METAL CASTING OF SCULPTURE

CARL DAME CLARKE

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BY

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Molding and Casting, Its Technique and Application

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Facial and Body Prosthesis

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DEDICATED TO

MY WIFE

MARJORIE ROWLAND CLARKE

PREFACE

This book describes in detail, and pictures step-by-step, the various processes of producing sculpture and ornaments in metal by the *cere perdue* or lost wax process. It gives scores of formulas and methods which have been known only by word of mouth. It exposes trade secrets which have been closely guarded by the worker in the past.

The ever-growing tendency today is to refine hazy verbal descriptions of art methods into specific written formulary. Tested formulary invariably produces uniform results in the hands of a skilled technician. However, the unskilled worker may miss some simple principle, and thereby obtain a faulty result. One novice in the casting profession complained bitterly that all local plaster of Paris was worthless, blaming the manufacturers and merchants. When the novice was asked how he mixed the plaster, he said, "I put the plaster in a bowl and add water. It gets lumpy right away." The experienced worker knows that in mixing plaster, the water is placed in a bowl and the plaster added to it. In this text, I have not only tested and retested the formulary, but I have tried to be specific in mixing directions.

I am indebted to Mr. Randolph Wardell Johnson for furnishing some of the illustrations, and to the various furnace manufacturers, who have provided engravings of their products. I am also indebted to Miss Frances Blackburn, who has helped me greatly in the preparation of the manuscript.

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CHAPTER I

GENERAL CONSIDERATIONS

Molding and casting are processes of reproducing an object in form, texture, and often color, identical in appearance with the original from which the copy or reproduction is made. To obtain such casts there are two main processes to be undertaken. The first is that of producing the mold or negative. The second is the making of the cast or positive from the mold. In other words, a mold is an impression of an object, whereas a cast is an impression of the mold. In science the finished cast or positive is sometimes called *moulage*, a word of French origin, *mouler* meaning to cast or mold. The words *negative* and *positive* will also be used as a means of simplification. I prefer the word *moulage* to express both molding and casting as a unit, though the term casting is often used alone by the novice to express both processes. In speaking of the original object from which a mold and then a cast are made, the word *model* and *pattern* will be used. In production casting the word *pattern* is inevitably employed to designate the subject from which the mold is made.

The purpose of this text is not to emphasize the history or theory of molding and casting, or the moulage process, but to describe its practical means of production in varying situations.

Such processes have been used for thousands of years in the fields of fine arts and commercial manufacture and are still used today. All sculptural works of importance are molded and cast. Even if the original clay or plasteline work is to be cut in marble, usually it is first molded and cast in plaster of Paris. However, the rubber mold lends itself for use directly on the clay model. From this rubber mold a wax cast can be made for confining in the *investment compound*. This is generally of a plaster-silica or clay mixture. The final *metal cast* is in most instances, made from a first *cast* in plaster which is made from the first *mold* of the original piece of sculpture which was *molded*.

A knowledge of moulage processes is essential to all sculptors. In fact, their original work frequently is so modeled as to make it suitable for the particular positive material in which it is to be cast or cut. For example, if a piece of sculpture is to be cast finally in terra cotta, it must be so modeled at the base or parts near the base as to give support to the weight of the entire cast. If the bulk of a terra cotta cast is supported on a thin, small part, such as a single leg, this part is likely to give way or droop before the piece of work dries or during the firing. Considerable attention should be paid to undercuts because an excess of undercuts increases the working time and expense of making the plaster piece molds necessary for terra cotta casts. The modeling for the cutting of a marble statue

must be solid, with few extending, unsupported parts. Modeling for bronze casting may contain many extended parts and undercuts because this metal is strong and can support weight. The plaster, agar, glue, or rubber mold used to cast the wax for the lost wax or *cire perdue* process in bronze casting lends itself well to the accurate recording of intricate undercuts.

The *cire perdue* or lost wax process of moulage making is today fairly well understood. This may be attributed to the writing of Cellini,[1] Lentz,[2] Hoffman,[3] Johnston,[4] and Clarke.[5] The man who has probably directed the production of more of this type of moulage in the United States than any other person is Ricardo Bertelli of the Roman Bronze Company. He is given credit for bringing the process to this country from Italy.

[1] Cellini, Benvenuto: *Autobiography.* Translated by J. Addington Symonds. The Harvard Classics, P. F. Collier & Son Co., New York, 1910.
[2] Lentz, A. D.: The Alfred David Lentz System of Lost Wax Casting. National Sculpture Society, New York, 1933.
[3] Hoffman, Malvina: *Heads & Tales.* Charles Scribner's Sons, New York, 1936.
[4] Johnston, Randolph Waddell: *Practice of Direct Casting.* Technical Studies in the Field of Fine Arts, Vol. VIII, No. 4. William Hayes Fogg Art Museum, Harvard University, Cambridge.
[5] Clarke, Carl Dame: *Molding and Casting.* The Standard Arts Press, Butler, Md., 1946.

CHAPTER II

PIECE MOLDS

It is customary in the *cire perdue* process to make a hollow wax-resin cast from either a piece plaster mold or from an *agar*, a *rubber*, or *glue* (*gelatin*) mold. The plaster piece molds and the glue molds have definite disadvantages in comparison with rubber molds. Some of these disadvantages are overcome by the agar mold. In any case it requires considerable experimentation on the part of the novice to develop his ability to make good molds regardless of the material he uses, whether it be plaster, agar, glue, or rubber. In other words, workable formulas will be given in this text for making good molds and casts. However, neither this text nor the actual observation of the work in progress will take the place of practical experience in doing the work itself. The worker must learn the technique by using the actual materials and making his own mistakes. For this reason it is obvious that he should prepare small molds and casts before he works with larger ones. Small moulages require less time and the mistakes are not so disheartening; for they can be corrected more easily. For obvious reasons he should first experiment with impressions in low relief rather than extensively under-cut subjects in the round.

Even today the Italians quite often use plaster piece molds for obtaining wax-resin casts for use in the *cire perdue* process. They often divide the original model into many pieces, especially the extended parts, and make piece molds of each part. These in turn are painted and poured with wax-resin compositions and then assembled to form a complete wax-resin cast. This cast is then invested into the composition to receive the metal. Needless to say, the making of plaster piece molds is quite often a more complicated and time-consuming process than the using of rubber, agar, and glue. Invariably rubber piece molds serve better, and decidedly fewer pieces are required. Furthermore, the rubber is as simple to use once the worker understands how to use it. Nevertheless, the object to be reproduced invariably governs the choice of the material to be employed.

The use of plaster piece molds does not warrent further description in this text. The process of making piece molds is well understood and is described in detail in *Moulding and Casting*.[1]

[1] Clarke, Carl D.: *Molding and Casting*. The Standard Arts Press, Publishers, Butler, Md., 1946.

CHAPTER III

GLUE MOLDS

The glue or gelatin mold is of camparatively recent origin, being less than a hundred years old. Either material will serve well for such a mold. Gelatin contains less impurities and is therefore more satisfactory; glue is less expensive and for this reason is more frequently employed. Both glue and gelatin may be used over and over again provided they are properly dried.

If the moulage worker has developed a technic for making rubber molds it is not likely that he will resort to glue molding, as rubber has many advantages over glue. In view of the fact that glue molding is an established procedure whereas rubber molding with the use of latex is comparatively new, the technic of glue molding will be described in detail.

Glue and gelatin were the first molding materials which were pliable to any great extent. By their use a great amount of undercutting is taken care of in the stretching or bending of the mold. Glue and gelatin molds have a rubberlike quality of springing back into their original forms when they are removed from the cast. This is accomplished by stretching the negative away from the positive in order to remove it from the mold. In other words, the elastic quality of glue or gelatin allows it to be pulled from beneath projections and around bulging surfaces after which it immediately springs back into its proper position.

Glue or gelatin are purely of animal or vegetable origin. That of animal origin is by far the most common.

Gel Strength is a term applied to the glue or gelatin mixture after it has set. Different types of glue or gelatin have different gel strengths. For example, the glue obtained from the hide of the animal is invariably the strongest and is sold as molder's glue. *Carpenters glue* is a loose term to mean any flake or granular glue that is used when in a liquid state to hold pieces of wood together. It should not be confused with liquid glue. This is flake or granular glue, previously heated with water and a chemical agent added to keep it in a liquid state. Such a glue does not gel but dries thereby giving it its adhesive qualities. It is entirely unsuited for molding.

Since the proper concentration of gelatin or glue and water requires a great amount of heat to bring it to the liquid state for pouring, it is undesirable for making a mold directly over living or dead tissue. Furthermore, it takes considerable time to cool and set, which renders it even more unsuitable. In cases where heat is likely to have a destructive effect on a protoplasmic subject containing undercuts, it is necessary to use a substance that can be applied in a liquid state and will not burn the subject, at the same time setting and taking the negative form of the

tissue upon which it is applied. For this purpose agar is used. However, a common fault in using both glue and agar is that they are applied too hot. It should be possible to hold a finger in either mixture before application is begun.

While the agar composition may be used for the same purposes as the glue or gelatin composition, the latter material produces stronger and more elastic molds. It is impractical to use gelatin or glue on a living subject because these materials take considerable time to solidify. Furthermore, they set below or too near body temperature. Hot wax compositions having high melting points cannot be cast in the average glue mold as the heat of the wax will remelt the mold. Waxes of a lower melting point can be painted into glue molds. Glue or gelatin are used mainly for plaster casting and next to rubber they offer one of the best methods for duplicating plaster casts in numbers. They may also be used over clay and plasteline models as well as wax impressions. The technics for using glue and gelatin are about the same.

Dental Formulary[1] gives the following formulas for the preparation of elastic molds of these materials:

	Parts by weight
1. "Carpenters' glue	20
Gelatin	20
Glycerin	35
Water	35
Cottonseed oil	20

Place the glue, the gelatin and the water in an enameled double (rice) boiler, let stand for twenty-four hours, heat until dissolved and add the glycerin and cottonseed oil with constant stirring."

	Parts by weight
2. "Carpenter's glue	200
Water	50
Soak the glue in water overnight, pour off the excess water and add:	
Glycerin	50
Melt over a low fire under constant stirring until the total mass weighs	250"

Frank Forrest Frederick[1] recommends that the glue or gelatin be broken into small pieces, then covered with cold water and allowed to stand for about twelve hours, after which the water that is not absorbed by the glue is poured off. I find that a more elastic mold can be made by adding 14 ounces of molasses to every 16 ounces of glue or 4 ounces of glue to every 16 ounces of gelatin. Mr. Frederick contends that gelatin is more elastic than glue and is not so easily affected by the heat created by the setting plaster cast.

Many casters use the gelatin or glue alone without adding any ingredients other than water. They simply let the glue soak in water for

[1] Frederick, Frank Forrest: *Plaster Casts and How They are Made*, 3rd Ed. The William T. Comstock Co., New York, 1927.
[1] Prinz, Hermann: *Dental Formulary*, 4th Ed. Lea and Febiger, Philadelphia, 1930.

about twelve hours, pour off the excess water and heat the glue in a double boiler, after which it is ready for pouring.

A very good elastic mold may be made as follows and withstands considerable heat.

	Parts by weight
Gelatin	6
Laundry soap	1
Glycerin	1

The glue is soaked in water for about twelve hours, after which the excess water is poured off. The mixture is heated until melted and glycerin and soap are added with constant stirring, until the soap is melted and thoroughly mixed in the composition. Different glues absorb water in various quantities, depending on the time of soaking. It is difficult to determine exactly how much water is necessary. Therefore, it is advisable to test a small amount of the glue during the heating process by pouring it on a cold surface, allowing it to cool, then pressing and stretching it to determine its hardness and elasticity. This mixture *will not remelt* so it cannot be used again.

By the use of sorbitol, glue-glycerin mixtures can be made more tough and resistent to heat. In fact, the flexibilizing or conditioning of glue or gelatin mixtures is a special and very important application of this material. The elasticity, ease of forming or molding, and hydrophilic character of gelatin-water jellies would make them very useful technically, but straight gelatin-water jellies or gels under normal atmospheric conditions dry out, shrink and harden. The drying out can be prevented by replacing a substantial amount of water by a polyhydroxylic hydrophile substance such as glycerin. This relatively stable gelatin or glue-glycerin-water composition finds one of its technical uses in flexible mold making. In the past, however, these molds have always suffered from sensitivity to high humidities and temperatures

It has been found that the addition of commercial sorbitol (arlex)[1] to the composition confers greatly increased toughness and body, and resistance to undue moisture pickup at high temperatures and humidities, without sacrificing desirable surface softness at low humidities.

Properly made sorbitol-glycerin-glue molds have consistently shown life approximately three times that of the ordinary glue-glycerin mold. This longer life is caused partly by the fact that sorbitol lowers the gel strength of glue mixtures to a lesser extent than does glycerin, and partly by the fact that sorbitol is much less soluable than glycerin in the organic solvents used as separating mediums.

The following formula will be found far superior to most glue mixtures for mold making:

[1] Atlas Powder Co., Wilmington, Del

	Parts by weight
Glue (dry)	33.6
Sorbitol (arlex)	25.2
Glycerin	25.2
Water	16.0

The sorbitol and glycerin are mixed with the water. The dry glue is added and the mixture allowed to stand overnight. It is then heated until melted. The use of a candy thermometer will enable the worker to hold the temperature down to 72 C. (160 F.).

In hot climates the glue can be increased by 50 per cent. In cold, dry climates the glue can be decreased from 25 to 50 per cent.

THE TECHNIC OF MAKING A GLUE RELIEF MOLD

Regardless of the formula that is used the technic of making a glue or gelatin relief mold is essentially as follows:

If a mold is to be made over a plaster cast, the cast should first be well shellacked or lacquered. It should then be brushed with a solution of one part of stearic acid and three parts of benzene or carbon tetrachloride, preferably the latter because it is not infammable. Equal parts of lard and tallow melted together and applied hot with a brush, or lard oil alone, will take the place of the benzene-stearic acid solution. In any

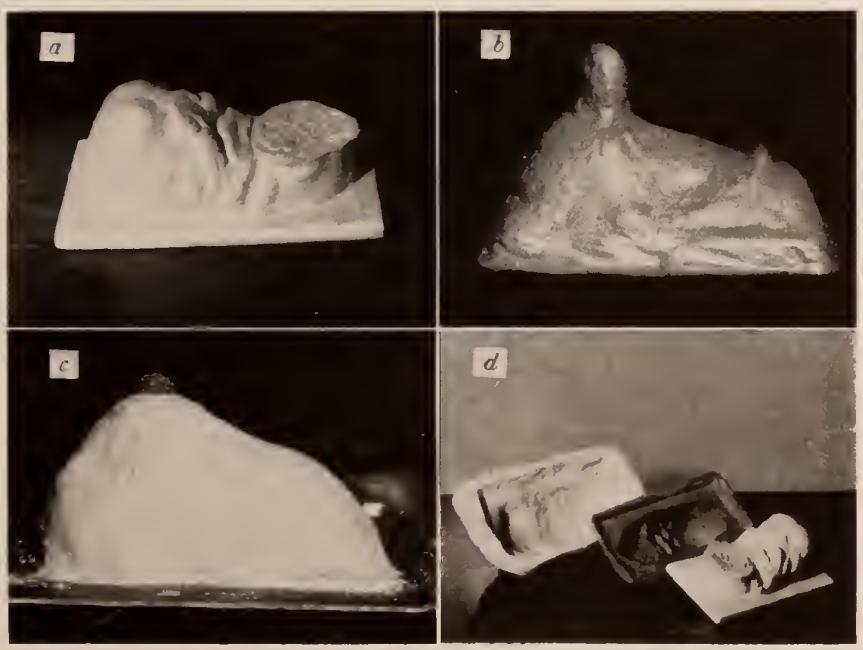

Figure 1. Making a glue relief mold. *a,* The subject is shellacked. *b,* Ribbons of clay are applied over the model to a thickness of about one-half inch. A cylindrical piece of clay is put in place to create an opening for receiving the liquid glue. The raised area to the right-hand side is added to register the mold in the mother mold. *c,* The mother mold is made in plaster, leaving the top of the cylindrical piece of clay uncovered. The mother mold is then removed and the clay taken from the model. The mother mold is shellacked on the inside and replaced over the model. The glue is poured through the opening. *d,* After the glue has set the mother mold and the glue mold are separated. This illustration shows the mother mold, glue mold and a cast.

event, the solution should be applied thin and sparingly, and not allowed to congeal and show the brush strokes.

In the meantime the glue or gelatin should be melted and allowed to cool to a point where the finger can be held in it without discomfort. In casting a relief impression a wall must be prepared around the cast to keep the glue within bounds. There should be no cracks under the wall which might allow the glue to escape from the enclosure. Such cracks may be filled in with clay or plasteline.

These walls may be made of wood. However, a clay wall may serve as well, if not better, on small models, as it can be made to conform to the outline of the model. If the model is large a wooden wall must be used since the weight of the glue would force a clay or plasteline wall apart. If a wooden wall is used it is shellacked and oiled in the same manner as the cast. When the glue has cooled sufficiently it is poured over the cast and allowed to set. After setting the mold is turned upside down for the casting.

Before casting with plaster, the mold should be painted with one of the above-mentioned oil separating mediums. Sometimes a concentrated solution of alum is first used to toughen the surface of the mold. If there is any doubt as to whether the mold will separate from the cast, the mold may be dusted after oiling with powdered talc or chalk. The plaster is then mixed and poured while quite thin into the mold. It is advisable to pour a little plaster at a time and gently brush it over the mold, in order to be certain that every crevice is filled and that no air bubbles remain.

The cast should be removed immediately when the plaster sets and before it begins to generate heat, as this heat will remelt the glue and destroy the mold. As soon as one cast is removed the mold can be washed with alum water, regreased, and a second cast poured. This is continued until the desired number of casts is obtained.

In making a wax cast for the cire perdue process, waxes of low melting point are painted into the mold when they are low in temperature but still sufficiently liquid to flow into fine details.

The main difficulty which the beginner experiences is that he often uses too much water with his glue. As a result the mold is weak and readily affected by the heat of the cast. This should be avoided and with a little experience the difficulty may be readily overcome.

In the event the glue softens as a result of the heat of setting plaster this can be overcome to a great extent by mixing the plaster with ice water. A mold that has been softened to a minor degree by the heat of setting plaster may be rehardened somewhat by the application of a concentrated solution of potassium alum. This is applied with a brush.

While sorbitol in a glue mixture toughens the resulting mold, it may cause a softening of the surface of plaster, especially if the molding composition was too high in water content. This may be overcome by using

a lacquer or varnish separating medium. Of course this softening does not effect the surface of a wax cast made in sorbitol—glue molds.

THE TECHNIC OF MAKING A GLUE MOLD OF A ROUND SUBJECT

A cast in the round can be duplicated in plaster of Paris by the use of the glue mold. Before starting the glue mold, the model is carefully studied to determine where the dividing seam lines will be placed. These must, of necessity, be so placed as to give the minimum of undercuts to the finished mold. It is good practice to outline the seam lines with a colored pencil before the work is begun.

The cast is first shellacked and then covered with a layer of clay or plasteline to the thickness of about one-quarter to three-quarters of an inch or more, depending on the size of the cast. This clay fills the space which will later be occupied by glue. To prepare such a covering the clay is first rolled out flat with a rolling pin or cut into slabs with a wire and applied in strips to the model.

Small solid cylinders of clay are then stuck to the clay covering at various levels. When the plaster shell is later applied, these cylinders will produce holes which will allow the escape of air during the time the shell is being filled with glue. A cone of clay is also added at the highest point of the model to serve as an opening for pouring the glue.

A clay wall is then built around the cast following the seam lines for the purpose of separating the two halves of the case or mother mold. Some workers prefer to put the clay wall in place before applying the clay strips. This is good practice for it is more easy to follow the seam lines which have been previously outlined. Registration grooves or notches are cut out of this wall, or they may be built as pyramids or hexagons so that both halves of the mother mold will fit together closely in perfect registration.

The shell is made by applying liquid plaster directly over the clay. This should vary in thickness according to the size of the model. If the cast is large, the shell should be thick and strengthened by means of *irons* which have been stuck to the set plaster shell with burlap or gauze that has been dipped in liquid plaster. However, since the case illustrated is comparatively small, such irons are unnecessary.

After half of the plaster shell has set, the clay wall is removed by pulling the wall toward the uncovered half of the cast and running a knife along the edge of the case. This leaves one-half of the model covered by the clay and shell.

The second half of the model is now covered with the thick ribbons of clay and the cylindrical forms of clay are added for air vents, as was done on the opposite half. A separating medium is painted on the edges of the plaster case or mother mold covering the first half of the model.

Figure 2. Glue molding of a subject in the round. *a*, Front view of the plaster model. The model is shellacked or treated with lacquer. *b*, Back view of the same model. *c*, Left-hand side view of the model. The line of separation has been drawn on this illustration. *d*, Right-hand side view showing the line of separation. *e*, Ribbons of clay are applied to cover one-half of the model. The left-hand side of this clay ribbon follows the line of separation. *f*, Half of the model has been covered with clay. Cylinders of clay as air vents have been placed on the surface of the clay. A wall of clay has been placed around the entire model to confine the plaster mother mold. Registration grooves for the mother mold have been formed by placing clay projections in the space between the wall and the clay on the model.

→

The plaster case is then made over the second half by the same method used with the first half.

After complete setting of the second half of the case, the two halves are separated and one-half of the case is left on the model. The clay is then removed from that half of the model which is no longer covered with the half of the case. A knife or modeling tool may be used to obtain a smooth surface on the edge of the clay that remains on the model.

Registration holes or notches consisting of half spherical depressions are pushed into the clay edges on the half that remains. This will insure the proper registration or fitting together of the two halves of the glue mold when it is completed. The half of the case that has been removed is well shellacked. When the shellac is dry, the mold is painted with the stearic acid-carbon tetrachloride solution, replaced over the model and made to fit perfectly with the opposite half of the case. The two halves of the case are securely tied together with soft iron wire. Glue which has cooled to a point where the fingers can be held in it is poured into the side that is not filled with clay. As the glue rises in the case to the point of the air vents or holes that were formed by the cylindrical clay knobs in the case, these openings are stopped up with clay to prevent the escape of the glue. The mold containing the cast is set aside for about twelve hours or until the glue sets thoroughly. When this has taken place the side of the shell covering the clay is removed and the clay taken out.

The glue on the edge should be painted with the stearic acid-carbon tetrachloride solution and dusted over with talc to prevent the two halves of the glue mold from sticking together.

The half of the shell which contained the clay is cleaned thoroughly, shellacked and painted with the separating solution on the inside, and replaced. The two halves are again tightly tied together and the open space is filled with glue. It should be borne in mind that the glue must not be hot enough to melt the set glue in the adjoining half. This may be determined by inserting a finger in the liquid glue. If it is uncomfortably hot, the glue should be allowed to cool to a lower temperature. However, it should not cool to a point where it begins to congeal.

The clay projection at the top forms a funnel-shaped opening for pouring the glue. *g*, The application of plaster of Paris to form the mother mold. *h*, Half of the plaster mother mold completed. The vent holes are left uncovered. *i*, The model as seen from the back with the clay wall still in place. *j*, The clay wall is removed. *k*, The back half of the model is covered with clay ribbons and smoothed off. Clay cylinders for vent holes have not as yet been applied. After these cylinders have been put in place, the edges of the plaster are shellacked and the opposite half of the mother mold is made in plaster. *l*, The plaster mother mold is opened. A knife point is then run along the edges of the mold, cutting into the clay so that a smooth edge of clay remains in one-half of the mother mold. The clay is then removed from half of the model. Round registration grooves for the two halves of the glue mold are pressed into the clay that remains on half of the model. The edges and inner surfaces of the half of the mother mold that was removed are then shellacked. The two halves of the mother mold are replaced and securely tied with wire. Warm glue is poured into the half of the mold which is not covered by clay. After this glue has set, the mother mold is opened and the clay is removed from the opposite side. The edges and inner surfaces of this half of the mother mold are shellacked. The edges of the set glue are greased well and the halves of the mother mold are retied together. Warm glue is then poured into the opposite half. After setting, the mold is opened and is ready for making the positive.

The mold is then set aside for a second time until the glue has set. After the setting of the glue, the two halves of both the glue mold and the shell are separated and the original cast is removed. The inside of the glue mold is now painted with a separating medium and the low melting point wax is applied for the cire perdue process.

Each section of a glue mold is painted with the wax before the halves are tied together. As these are painted the protruberances along the edges are scraped away so that the two halves of the cast will fit together perfectly. As soon as the wax has set to a point where it will not flow, the two halves are tied together securely. The resin-wax mixture is then poured into the mold to fill the crevices between the halves and build up the desired thickness of the cast. This thickness will eventually be replaced with metal. After the excess wax-resin is poured out the investment composition to form the core is poured in. After this sets the mold is removed.

CHAPTER IV

KOROGEL OR KOROSEAL FLEXIBLE MOLDING COMPOUNDS

The B. F. Goodrich Company, Akron, Ohio, pioneered an elastomeric mold of plasticized vinyl chloride and similar materials, which has been in growing use since the early 1930's for the production casting of gypsum cements and similar materials. These molding compounds are available is a number of grades and qualities which permit the casting not only of the gypsum cements, but also of the modified acid phenolic and urea base types of resin, and some polyester types, to the most intricate shapes.

These Korogel or Koroseal molding compounds are used in a similar manner to that of the glue-gelatin mixture in the art casting field. Because of their controlled resistence to water, mineral oils, and greases, their lack of need for parting or separating compounds, their resistance to all normal temperatures up to well over 93.3 C. (200 F.) and to bacterial decomposition, their close dimensional retention, and their insignificant shrinkage with time, they have definitely proved themselves of value as mold making materials.

In addition to the art casting field, the Koroseal flexible molding compounds are particularly applicable to the production of masks for ceramic use and for manufacturing jewelers' applications. Certain types of Koroseal FMC can be employed for "cire perdue" or the lost wax process for making a mold. Typical of this application on a production basis is the Austenal method of application covered by Patent No. 2,337,036, and for direct use as precision foundry patterns a number of patented applications such as the Bean process, Patent Nos. 2,402,528 and 2,349,806, wherein the facings of Koroseal flexible molding compounds are mechanically attached to gypsum cement backings for precise work.

For the repeat reproduction in quantity of advertising novelties, instruction models, etc., the flexible molding compounds of this type have proved themselves to be generally satisfactory.

All of these applications require that the Koroseal FMC be melted and poured as a liquid and the instructions which follow are given as a guide in handling.

Melting:

Radiant heat melting is recommended with thermostatically controlled bottom heat on the melting vessel. Bottom heat may be supplied from oil-bath, sand-bath, or from electrically heated coils. For most uses, standard electric roasters, enamel lined, meet requirements except the radiant heat. This may be supplied with electric heat lamps, coils, or elements supported over the melting vessel in an adjustable manner. Enamel melting vessel should be clean and free from any breaks in the enamel so the

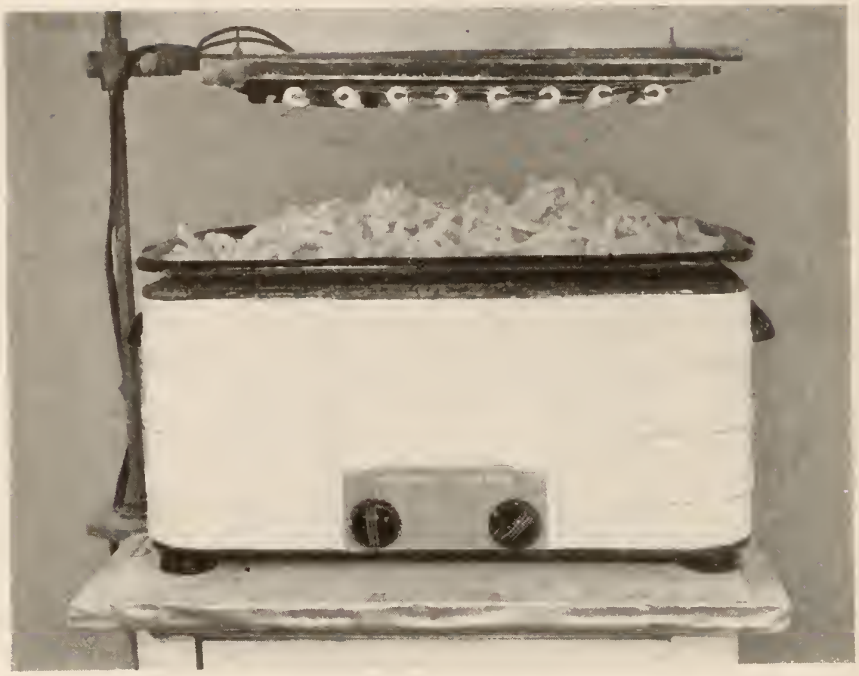

Figure 3. The melting set-up, using an electric roaster. The picture shows an electric roaster with adjustable height heat element on top. The enameled melting pan rests on a ½" pad of mineral wool. Bottom heat is thermostatically controlled at 225-275 F. (107.2-135 C.), depending on the grade being melted. *Courtesy of the Perma-Flex Mold Co., Columbus, Ohio.*

Figure 4. The melting setup using an infra-red (radiant heat) lamp. The stainless steel pan is resting on a mineral wool insulating pad. No bottom heat is needed on small melts. *Courtesy of the Perma-Flex Mold Co., Columbus, Ohio.*

molding compound does not contact the raw metal beneath. Wherever possible for production, use 18-8 stainless steel or its equivalent, as this is preferred to enamel for heavy duty melting service because of its non-chipping character.

The quantity of molding compound desired is placed in the melter. The rheostat which controls the bottom heat at 107.2 C.-135 C. (225-275 F.) is set. The operator will find temperatures to his liking as he becomes more adept in handling the material. This is the recommended temperature for safety. The top element is brought down to within six or seven inches of the top of the molding material in the melting vessel. the rheostat is turned on to maximum heat and the mixture is watched closely for a few minutes to see that the element is not too close to scorch the melt. It will be noticed that the molding compound melts quite freely on the top, running down toward the bottom of the mixture. It is recommended that the material be stirred considerably during this melting period.

For small melts up to four or five pounds, a 375-watt infra red lamp directed into the top of a stainless steel or enameled dipper containing the Koroseal FMC serves as a rapid and efficient melter. The pan should be placed on a mineral wool or other similar insulating pad to prevent heat loss from the bottom.

After the molding compound is melted it will be noted that there may be fine small bubbles over the surface of the melt, but these will soon break. This period usually takes fifteen to twenty-five minutes of surface radiant heating after the molding compound becomes liquid throughout the entire mass. By surface heating until all bubbles have broken and the melt is clear, internal defects from this source are eliminated.

PREPARATION OF MODELS:

NON-POROUS MODELS:

Glass, metal, china, marble, or other non-porous models should be heated gradually to 93.3 C. (200 F.), or slightly higher, greased lightly with mineral oil (10-W, 3-in-1, Finol), and cased in a metal shell or other non-porous container, and the liquid Koroseal FMC poured over the model in any convenient manner. The Koroseal FMC, after cooling, may be peeled off the model, or cut in any convenient manner to permit of ready removal from the model. Care must be taken in cutting to do the least possible damage to important surfaces to be cast.

PLASTER MODELS (Uncalcined):

Plaster models of molding, art, statuary, pottery, dental, casting, hydrocal, in fact of all gypsum plasters not formulated to withstand heat, begin to calcine or lose chemically bound water under heat at temperatures as low as 65.5 C. (150 F.) Heat treatment, while desirable, must be kept below 65.5 C. (150 F.), or there is danger of cracking,

softening, and disintegration of the model. Plaster models that have not been heat treated are not completly satisfactory for forming Koroseal FMC *without special processing methods.**

PLASTER MODELS (Calcined):

Koroseal FMC may be formed directly against heat treated investment plaster, metal casting plaster, or other plaster compositions, which will succesfully withstand baking out at 135-176.6 C. (275-350 F.) to remove the free and most of the chemically bound water. However, difficulcies are encountered in using these materials *without special processing methods.**

POURING:

For models made of metal, glass, marble, or other like material, a surface lubrication with very thin mineral oil—Dow-Corning No. 7 Compound (a constant viscosity grease about the consistency of vaseline) or Dow-Corning Mold-Release Fluid—is helpful in stripping the cooled Koroseal FMC from the model. (The latter two are preferred, although much more costly, since they maintain uniform viscosity and can be applied in extremely thin coats.) It cannot be emphasized too strongly that all models must be dry, since the Liquid Koroseal FMC's flow well between 93.3-176.6 C. (200-350 F.), depending on type. The Koroseal FMC is flowed on in such a manner that it will rise up around the model and not entrap air bubbles.

It is also desirable to maintain the Koroseal FMC fluid by external heat from a radiant heat lamp until it has chilled and contracted around the model. (The vacuum technique used in the PERMA-FLEX method is adaptable to models containing internal air in their structure.)

Models of Plasteline, wood, wax, and all substances which will not withstand the pouring temperatures of Koroseal FMC must be duplicated in gypsum cement by other processes, such as the piece mold technique previously described, rubber latex molds, agar molds, or gelatin molds. These techniques are recommended where the finished Koroseal FMC mold is to be used as a production device, inasmuch as the gypsum cement model can be perfectly surface finished before Koroseal FMC fabrication. Koroseal FMC molds made from the resultant secondary model will then transmit the most minute detail to production castings because of the elimination of parting compounds or surfacing treatments.

PAINTED MODELS:

No attempt should be made to pour Koroseal FMC over painted models. It will soften and remove almost all types of decoration, except

* One method (vacuum) used by The Perma-Flex Mold Company, Columbus, Ohio, has been eminently successful and has been proved with several years' service. It is covered by United States Patent Application, Serial No. 575,036, owned by United States Gypsum Company. The process is made available to potential users of thermoplastic flexible molding compounds at nominal expense by arrangement between The Perma-Flex Mold Company and United States Gypsum Company.

fired-on china colors. Plasters containing dextrine (art, statuary, casting, etc.), are not desirable, since the dextrine "skin" comes to the surface irregularly in drying, and dextrine burns to caramel at about 148.9 C. (300 F.)

CLAY AND PLASTELINE MODELS:

Hot Koroseal FMC will melt some modeling clays of the wax base type and this type of model is unsatisfactory. With care Koroseal FMC can be poured over models of the "water-clay" type, provided these are greased lightly, and massive enough to chill Koroseal FMC quickly so that steam bubbles do not develop.

COOLING OF KOROSEAL FMC:

After pouring, Koroseal FMC must be allowed to cool out slowly until it is cold, before removal from the model. It is recommended that it be allowed to stand overnight. In warm weather, it may be necessary to cool it out in the refrigerator. Complete gelling is necessary, in all cases, especially where dimension tolerances are close.

There is a contraction during cooling and it is desirable always to maintain the Koroseal FMC fluid with external heat at the point or points of the mold, such as pouring gates, etc., where this contraction will do no harm. The Koroseal FMC must congeal directionally away from all surfaces being reproduced in order to prevent contraction away from these surfaces during the cooling period.

CHAPTER V

THE AGAR MOLD

Agar or Japanese glue, as it is often called by the statuary casters, is possibly the most common material used in mold making for the cere perdue or lost wax process. This is mainly because the agar mold easily withstands the high temperatures of the wax-resin mixtures employed in forming the positive.

An agar-water mixture has the property of melting at slightly below 100 C. (212 F.). However, it does not return to its semi-solid or set state until it cools to a temperature of about 40 to 44 C. (105-112 F.). Since this is just above body temperature 37 C. (98.6 F.), agar, which has many of the qualities of glue, also suggests itself for plastic casting of living subjects. This composition may be applied in a liquid state before it cools to its setting point, without injury to living or dead tissue.

Agar and water alone are not suitable for plastic casting as this mixture is too fluid to remain on dependent surfaces and tends to fracture or crumble too easily. It is necessary for the composition to contain other substances, such as preservatives, tanning agents and material which will increase the colloidal binding power of the agar and cause the particles to hold together and become more rubber-like. This is an important material for making molds of living and dead tissue, as well as for non-protoplasmic subjects.

Dr. Albert E. Butler in 1934[1] published a formula for making an agar composition for molding which is as follows:

> "To 6 oz. agar add 1 qt. water. When thoroughly soaked, boil in double boiler and add 3 lbs. glycerine. Continue cooking until water is well evaporated. Add a few drops carbolic acid. Allow to stand until evaporation is complete. The resulting rubbery mass should be cut into small cubes and is ready for use. Heat, as before, until liquefied and after cooling somewhat, pour over the object to be cast. Harden the inner mold surface by coating with alum water before pouring hot wax into it. It may be used for casting objects in either wax or plaster."

At the present there are numerous commercial sodium and potassium alginate or algin compositions on the market that are suitable for dental mold making. Among these are *Coe-Loid Powder, Zelex, D. P. Impression Colloid,* and others, They were produced as substitutes for the well-established agar compositions. In some ways the alginate is inferior to agar; in other ways, superior. In any event, at the present time these compositions are so new that considerable research should be done on them before it can be stated that they are better suited for moulage work than agar. The great advantage of sodium or potassium alginate

[1] Butler, Albert E.: *Building the Museum Group.* Guide Leaflet No. 82, The American Museum of Natural History, New York, N. Y.

compositions lies in the fact that they can be used immediately after mixing with cold water and require no heating. However, at the present they can not be reused but a new composition must be employed in making each moulage. For small impressions they serve admirably well, but the large impressions of massive statuary require large molds which may be difficult to make with the present commercial compositions of sodium or potassium alginate. Furthermore, the expense of the alginate mixtures may cause their use to be prohibitive. However, it is logical to reason that soon these difficulties may be overcome.

For those who wish to pursue this subject the U. S. Patent: *Materials For Taking Impressions for Dental and Other Purposes, No. 2,249,694* should be studied. This is essentially on *sodium alginate,* (a derivative of kelp) whiting and plaster of Paris. Further information may be obtained on Carragar* another kelp material.

Because the alginate products are still in the experimental stage the well established agar compositions will be described in detail. Compositions of agar have been standard for use in moulage work for many years and will continue to be used for years to come.

In preparing a plastic negative composition the worker must bear in mind that he is making an effort to prepare a product having definite, necessary qualities which may be enumerated as follows:

1. It must, in one state, be sufficiently liquid to flow into the smallest cavities.
2. It must in another state be viscous or adhesive enough to cling to a vertical plane against the pull of gravity.
3. It must not be harmful or painful to the living or dead tissues of the human body when it is applied directly to such tissues.
4. It must be of a nature which will change from this liquid state to a solid or gel state known as *setting* within a reasonsble length of time for the purpose used. When the material is applied to the human body, a reasonable length of time for the setting is between five minutes and one-half hour. It is advantageous to be able to hasten or retard this setting time.
5. The setting point should be sufficiently high to allow the materials to set in a short period of time, yet not so high as to make it necessary to apply the composition at a temperature that would be harmful to the model.
6. After setting it should be firm. The material should have sufficient strength to hold firmly together under stress of a small amount of pressure so that it may be relieved of undercut surfaces.
7. After setting, it should have enough elastic quality to take its original form after being stretched or bent away from an undercut surface.

* Manufactured by the *Kim-Ko Company,* 4830 S. Christiana Avenue, Chicago, Illinois.

8. It should be possible to use this material for making *waste molds, piece molds, and draw molds.*

9. It should be possible to pour or "paint" hot wax or resinous positive compositions into a set negative without destroying the mold or any part of it in so doing.

10. It should be suitable as a mold for the making of casts of plaster of Paris and similar materials, such as Portland cement, oxychloride cement mixtures, wax, and rubber.*

11. If the mold is composed of expensive ingredients, it should be possible to use such materials as constitute the mold over and over again, otherwise the materials should be so inexpensive that they may be thrown away after they have been used.

The compounding and technique of using agar compositions for obtaining impressions of human tissue have been discussed at considerable length in previously published articles.[1] [2] Recently a number of articles have appeared which add materially to the information on this subject. Most notable among these is the review by Paffenbarger[3], who considered in detail commercial agar preparations. This author has perfected devices for testing compositions as to their strength under pressure, their elasticity, and their flowing qualities. He presents a set of general specfications for making agar compositions suitable for use in dentistry as a material for intra-oral impressions. He does not explain, however, how agar compositions may be compounded or changed to suit specific cases. It is the purpose here to include a discussion of this important subject.

Most workers in the cere perdue pr ›cess simply add water and glycerin to dry agar until the desired working consistency is reached after melting together.

Since sorbitol (Arlex†) imparts considerable strength to agar, I feel that the following formula is far superior. Some glycerin is used in this formula to increase the fluidity of the mass. Otherwise it would flow too sluggishly into fine details.

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* A hydrocolloidal composition, such as one containing either agar, sodium alginate, or glue, is not a suitable molding material for the making of porcelain or terra cotta casts. The reason for this is that these molds do not absorb water from the positive material. Plaster molds, however, do absorb water when the porcelain or terra cotta slip is poured into them. Agar and glue molds have strength enough to allow the softer porcelain or terra cotta pastes to be forced or pressed into place.

[1] Clarke, C. D.: *The Technic of Molding and Casting for the Medical Sciences*, J. Lab. & Clin. Med. XXI:68, 1935.

[2] Clarke, C. D.: *Molding and Casting*, Baltimore, 1946, The Standard Arts Press.

[3] Paffenbarger, George C.: *Hydrocolloidal Impression Materials; Physical Properties and a Specification*, J. Amer. Dent. Ass'n. XXVII:373, 1940.

† Atlas Powder Co., Wilmington, Delaware.

	Parts by weight
Agar (dry)	33.6
Sorbitol (Arlex)	25.2
Water	16.0
Glycerine	25.2

Another basic agar formula may be considered. It should be realized that this formula is flexible and can be changed to suit specifie requirements. Methods for changing the formula will be given following the reason for using each chemical.

Agar (dry)	4 ounces
Water	100 ounces
Zinc oxide	1 ounce
Oxyquinoline sulfate	10 grains
Cellucotton	½ ounce
Cotton	15 grains

Glycerin and sorbitol may be used in most agar mixtures to increase flexibility. However, these ingredients cause a skinning or softening of the surface of plaster casts made in such molds. They have no deleterious effects on wax impressions.

Agar is the basic substance. When mixed with water it liquefies completely at 100 C. and does not jellify or start to set until it cools to about 40 C. Paffenbarger has found this setting point to vary from 36 to 44 C. in different batches of agar. It is this property of agar that makes it suitable as a molding material for use on living human tissue. The more servicable composition should set at or near 44 C. If it sets below body temperature, 37 C., it is less satisfactory for use on living human skin. Agar differs greatly from gelatin or glue in this respect. It will adhere closely to the melting and setting points when mixed with water in spite of high or low concentrations. The amount of water in a gelatin or glue mixture plays a more important part on the temperature of its setting or jellying point. The higher the water content, the lower will be its setting point, and vice versa.

According to Paffenbarger, manufacturers report that they find it impossible to procure agar which is uniform from batch to batch. Agar from different species of seaweed from various parts of the world, or from different parts of the same country, shows varying characteristics.[1] Therefore, it becomes necessary to refine the crude product before it can be used as an impression material. The commercial powdered agar has less strength in solution than either the granular or shredded agar, but the powdered agar goes into solution more readily. The higher the agar content, the stronger the composition will be, but its flowing qualities will be reduced accordingly. The agar composition must possess a viscosity that will permit easy flow into the smallest details to obtain accurate impressions, such as the fingerprint pattern. If the flow is too sluggish,

[1] Yanagawa, Tetsunosuke, and Nishida, Y.: *Study of Agar-Agar, II.* Reprints, Imperial Industrial Research Institute, Osaka, Japan II No. 14, 1930.

air bubbles and lap or border lines will be formed in the mold, which, in turn, will produce a defective cast. The agar content, as well as each of the other ingredients must be balanced against one another to produce a composition suitable for making intraoral molds, molds of the skin surface, and molds of inanimate objects. For example, a mold of the gum surface is made by pressing a tray filled with agar composition against the gums. Its fluidity is more viscous because the pressure exerted in a comparatively small space has a tendency to reduce the possible formation of air bubbles. A composition suitable for application with a brush, should be less fluid, since it must flow by gravity without pressure into every detail. It must be sufficiently viscous, however, to remain where it is placed in adequate quantities to obtain a mold of the desired thickness. A less viscous composition may be poured over an inanimate protoplasmic specimen, such as a part of the viscera, or a nonprotoplasmic specimen, such as a plaster cast placed in a walled area or a closed mother mold. In many cases the viscosity of the agar may be controlled by the water content of the mixture. In other words, the same mixture may be used for all three purposes if the water content is changed to suit the specific case. However, this is not the ideal method. The mixture should be compounded to suit definite requirements, because the agar content of a mixture often determines its setting strength or elasticity. Other ingredients, such as an excess of alum and iron sulfate, will reduce this strength despite the small amount of water used.

Water is an important factor in the plasticity and friability of agar compositions, in both the liquid and set states. The water content must be balanced against all other ingredients. Regardless of the other ingredients, if there is too much water in the mixture it will lack strength and elasticity. The agar content imparts these desirable properties to the mixture. The remaining ingredients offset difficulties that can and do arise when an agar-water mixture is used for molding.

Zinc oxide, talc, whiting, and similar nonsoluable earths and minerals mix physically with agar but have little chemical effect upon the composition as a whole. They give the mixture bulk and weight. Their main use is to change the chemical action of a setting plaster cast that is made in an agar mold, or to absorb any substance that may be excreted from the agar during and after setting. Such secretion can cause a softening of the surface of a plaster cast made in an agar mold. In other words, if these fillers or absorbing agents are not included, a plaster cast made in an agar mold does not set properly. There are other substances, such as borax, sodium chloride, and sorbitol which have a chemical action on agar compositions, materially toughening them and at the same time reducing the plasticity or flowing qualities of agar compositions as a whole. Borax may be substituted for zinc oxide; it causes the resulting mixture to be more elastic if the cast is to be of wax. Such a mold has a detrimental effect on the plaster cast. It is possible, however, to balance the borax

or sorbitol against the zinc oxide, talc, or similar earth pigments to prevent this softening or "skinning" of the resulting plaster cast, and at the same time produce a more elastic mold. In fact, concentrated sorbitol-agar mixtures have a strength that is a hundred times greater than that produced by ordinary commercial agar molding compositions. The latter compositions serve their purpose well in the cere perdue or lost wax casting process as an intermediate step in making metal casts of sculptures. These mixtures will have to be perfected for use as a molding material for plaster casts.

Oxyquinoline sulfate is probably the best preservative for agar compositions because it prevents bacterial growth over a long period of time. It is not as volatile as thymol, nor is it as toxic as phenol or sodium fluoride, all of which have been used without complete success. Sodium fluoride is quite toxic in large quantities, but it has its place as a preservative for colloidial jellies that are applied to inanimate nonprotoplasmic subjects. Oxyquinoline sulfate is used in such small proportion that it has no effect on the plasticity of the agar in the prejelly state.

Cellucotton and *cotton* may be grouped together, since they have the same mechanical effect on agar mixtures, the effect being purely physical and not chemical. When these fibers are dispersed throughout an agar composition, they have a mechanical influence on the mixture, thereby holding it together. The cotton fibers are much longer than those of the cellucotton, which is a wood product. The amount of cotton fibers used must be kept low, for they tend to collect on the spoon during stirring and form in knots or clots throughout the mixture. These two substances, especially the cellucotton, increase the internal friction of the mass in both the liquid and set states. In other words, they give it body and reduce its flowing properties or plasticity.

Some manufacturers have incorporated rubber cement or para rubber dissolved into one of its solvents, such as benzine, into their agar compositions. After considerable experience in carrying out over two thousand experiments with such mixtures, I have come to the conclusion that the rubber, even when incorporated properly, is not only valueless in the mixture but is one of the most difficult ingredients to disperse evenly throughout the mass. It mixes only physically not chemically, and provides thousands of tiny rubber bands that in themselves exert less mechanical influence in holding together the particles than does the same amount of cellucotton. I am inclined to believe that the commercial manufacturer includes rubber purely for its psychologic effect on the buyer. It is reasoned that since rubber is tough and elastic, it should impart these qualities to agar compositions, but I have found no evidence of such effects. Tests and analysis have shown that the commercial products containing rubber were less elastic that those without it.

Technique: The basic formulas mentioned in this text can be used for the various types of molding specified. As in all types of work,

however, the manner in which the formula is compounded and used determines the quality of the finished product. For example, an impression of the hand may be made by painting or pouring the mixture over the skin surface. Both methods have their advantages and disadvantages. Invariably, less of the mixture is required in a painting process than in a pouring process.

Thus agar molds are not sufficiently strong by themselves to hold their shape without crumbling or cracking. It has, therefore, become necessary to follow one of two procedures to obtain a good mold. The first is to apply a plaster or a wax-resin shell over the thin agar mold so that it will not warp or break. The other method is to reinforce a thick agar mold with metal supports or with an armature.

A single thin painted layer is generally reinforced by means of a plaster rather than a wax-resin shell or case. It would be logical to reason that this double molding process requires more time to complete. On the contrary, this is not true, for the thin layer of agar composition sets quite rapidly and the plaster may be mixed thick, or its setting time may be accelerated by the addition of sodium chloride or potassium alum. It is practical because detail on the inner surface of the case or shell is not necessary. In this manner both the agar mold and the shell set rapidly in the same length of time that would be required for a thick agar mold or a detail plaster mold to set.

When applied with a brush the thin layer of agar composition obtained in painting shrinks and cracks rapidly, providing it contains no glycerin or sorbitol. Therefore, the cast must be made soon after the mold is removed from the subject or the mold must be kept in wet towels if considerabe time elapses between the making of the mold and the making of the cast. The same rule applies to the making of impressions of the face as to other surfaces of the body. I have learned from experience that in spite of these drawbacks better results are obtained with the thin agar mold and the reinforcing plaster shell.

Here it may be contended that a plaster mold could have been made in the beginning without the use of agar. This is erroneous for three major reasons: (1) The plaster does not record as much detail as the agar; (2) the mold is more difficult to remove from the subject, and (3) the cast is decidedly more difficult to remove from the mold.

In compounding agar mixtures all of the dry materials are mixed in the water which should be at room temperature. If hot water is used, the agar may gather in lumps. The composition is placed in a double boiler and heat is applied, and the mixture is occasionally stirred until it is a smooth homogeneous mass. It is ready for use immediately ofter preparing and cooling to a point about 10 C. above body temperature (37 C.). The double boiler is not necessary if the mixture is constantly stirred during the entire heating period. If it is not continuously stirred the

mixture will not only burn but will form a thickened mass at the bottom of the cooking pot.

This agar composition serves as a stock mixture and can be used over and over again. Each time it is used a certain amount of the water is lost by evaporation or conversion into steam. When the mixture is re-used, it is best first to place a small amount of water into the cooking pot before adding the agar composition. The mixture is then added to the boiling water, a small amount at a time, while constantly stirring to prevent burning and to hasten the mixture into becoming a homogeneous mass.

Applying the Agar and Mother Molds

After the composition for the agar mold is prepared and cooled, it should be ground in a food chopper. It may then be stored in airtight, rustproof containers. Such containers may be made from wax-coated cylindrical cardboard boxes or glass jars. The composition should be moist but should not contain enough water to be pressed out as drops when pressure is applied on a small amount held in the hand or between the forefinger and the thumb. If the material seems too dry, more water may be added. In preparing the composition for making an impression an amount is taken which will fully cover the intended surface to the desired thickness. There are two methods of using agar compositions. The first is to apply the mixture to the model, then make the mother mold. The second method is to make the mother mold, then pour the agar composition into this closed case. The first method will be described at this point. The second method is described in Chapter VIII.

The ground agar composition is placed in a double boiler with a lid and heated, with occasional stirring, until the mass becomes the consistency of thick cream At this point the mass is at about the boiling point of water. are too hot have a tendency to stick to the model.
It is then allowed to cool to a very few degrees above body temperature before being applied. It is well to begin applying the mass just as soon as the application does not cause any discomfort to the inserted finger. This should give the worker plenty of time to work the composition into cracks and crevices before it sets.

The temperature may be tested by inserting the tip of a finger into the warm mass. If it is too hot, application should not take place until the temperature has been lowered. It is suitable for use when a small amount can be held on the back of the hand without discomfort. It is absolutely unnecessary to cause any discomfort because of the heat of the composition, as it can be used at a temperature that will be neither harmful nor uncomfortable to the touch. Furthermore, agar mixtures that are too hot have a tendency to stick to the model.

In using the agar composition on living subjects, it is *not* necessary to grease or otherwise prepare the surface of protoplasmic subjects as

this material does not stick to skin, cardboard or similar substances; however, oil type separating mediums facilitate ease of separation. Agar can be applied directly to the surface to be molded with a bristle brush, spoon, spatula, or a syringe. It should be applied until the mold is one-quarter to one--half inch thick. Sometimes it is put on in thin layers or ribbons with a flat nozzle syringe. If it is used in this manner the first layer should still be soft before applying the second layer, otherwise the two layers will not stick together. If the composition contains an excess of glycerin or grease, this also prevents the various layers from sticking. This addition of alum has a tendency to minimize this danger. Frequently border connections between two applications of agar composition that have been applied with a syringe have a tendency to contain air bubbles. This may be avoided by rubbing the new application of agar into the old application. Where possible it is always best to apply the second coat before the first has fully set. The composition should be worked into all small undercuts, such as the rims of the exterior auricle or the inner parts of the front top of the external ear. The agar composition should not be stirred or moved in the last stages of setting, otherwise it is considerably weakened and may produce a cast which falls apart or crumbles. These difficulties can be overcome by pouring the mass into closed mother molds over the model.

There is no danger of water that is under body temperature mixing with the composition. It will serve only to cool the mass and thereby hasten the setting. An agar mold should never be removed until it has set throughout. This composition is a good insulator of heat and therefore may be set on the outer surface but still be soft within. The entire mass must fall below 40 C. before it is safe to begin making the mother mold.

Reinforcing Agar Molds: If the agar mold is of sufficiently large proportions, as would be an impression of a face, an entire head, or a leg cast in two pieces, it is very important that the mold be reinforced to keep it from breaking on removal. The best method of strengthening an agar mold is with plaster of Paris. This is simply applied over the set agar mold or the agar is poured into set mother molds. If plaster is used, the undercuts next to the mother mold must be small. In such a case, the mold will often remove itself by gravity if the caster places the subject or the part that is being cast in a position which will allow gravity to take its course.

CHAPTER VI

RUBBER MOLDS

General Considerations

Since rubber can be used directly on the clay model, it will be discussed in detail. Rubber in the form of sap from the rubber tree (latex) is a water-soluable liquid that can be purchased in two forms: common unvulcanized latex, and vulcanized latex (Vultex).[1] It is prepared in many consistencies or concentrations and in formulas already mixed. The latex or vulcanized latex should be purchased in definite concentrations and developed according to one's own formulary. This can be used as a medium into which are mixed various substances, such as clays, sawdust, wood flour or cellucotton (fillers) to form a paste for application to the model in making a tough, flexible mold. Coagulating agents may also be added to set up the rubber when it is poured into a closed *mother mold*. Other substances may be added for various purposes, as will be explained later. Nevertheless, a flexible mold can be made with vulcanized latex and cellucotton alone. Other chemicals, such as vulcanizing agents, antioxidants and ingredients to facilitate quick setting, are usually added to common latex. However, the basic idea in making rubber molds is as follows:

A mixture of latex is first applied to the model in order to obtain an impression of the details. This corresponds to the thin plaster-water mixture which is first applied to a model to obtain a rigid plaster mold. A plaster-water mixture thickens during setting; the latex-filler mixture is thickened by the edition of more filler or by coagulating agents. After the details of the model are coverd with a thin latex mixture, the filler is added to latex in the mixing bowl until it reaches the consistency of a paste which will not run from a vertical surface. As a matter of fact, the rubber mixture thus becomes of the same consistency as a plaster-water mixture during the advanced stages of setting. Too much filler will cause coagulation of the latex, making it difficult or impossible to handle, in the same manner as will the use of too much plaster in a plaster-water mixture. As a result such a mixture is rendered unsuitable for application. A rubber mold is not always poured in the same manner as a glue or agar mold. It is generally applied as in making a plaster waste mold. The case or mother mold is made *after* the rubber mold is completed rather than before, as in glue molding. This information should be borne in mind while considering the more detailed description of rubber molding which follows.

[1] General Chemical and Latex Corporation, Cambridge, Mass.

For many years rubber, in the form of dissolved sheets of para rubber, has been used extensively for molding and casting. Such work has been rather tehnical for the average caster and was shunned for this reason. However, the use of latex or natural rubber sap in recent years has simplified the process to a great extent and, as a result, rubber is rapidly taking the place of agar jelly or gelatin glue molding. Heat may be used to advantage in preparing a vulcanized mold of a latex composition, but it is not necessary. The heating or vulcanizing process greatly reduces the possibility of shrinkage. Latex casting is also used for positives, such as toys, shoes, and medical supplies.

Most rubber compositions employ latex as a base. As a rule, they contain ammonia or a similar alkali to keep the rubber suspended in the colloidal state. To these constituents are added various fillers, such as wood flour, clay, or talc and silica flour. To facilitate quick setting, ammonium chloride or epsom salts and similar metallic salts may be used to the extent of about 1/100th part of the total ingredients. However, this may vary according to the experiment. Calcium formate in 6.5 per cent concentration may also be used.

The latex is used as a base to which the fillers, the quick setting and vulcanizing ingredients can be added. It is well to remember that latex mixtures having a high water content are more likely to shrink and warp than those containing a small percentage of water. However, they can be more highly filled. Molds which have not been vulcanized also shrink more rapidly than those which have been vulcanized. Vulcanizing the mold is a simple procedure and only requires placing the mold for a period of time in an oven in which the temperature may be reasonably controlled. The mold may also be vulcanized in steam and hot water, but this procedure is usually avoided by the average worker, because it is too technical and complicated. However, with the directions to be given later, it will be found that the vulcanizing procedure can be quite simple.

Latex, as stated before, is the natural sap of the rubber tree. It is usally preserved before distribution by the addition of ammonia to prevent decomposition and coagulation. This addition is very simple. A predetermined amount of ammonia is added by the distributor to the fresh latex. This will keep the particles in suspension. The ammonia may be added either in liquid form or, preferably as ammonia gas. Should a latex-water mixture separate as cream from milk or become lumpy, additional ammonia may be added as a liquid.

The moulage worker should not confuse latex with caoutchouc or para rubber. These terms apply to coagulated latex, which may be redissolved with benzene, carbon disulfide, naptha or similar liquids, pro-

vided it has not been vulcanized, and is not readily affected by water. To obtain caoutchouc the latex is either heated or treated with acetic acid to cause coagulation.

Rubber in the water-soluable liquid form, or latex proper, may be diluted with water. The user of latex can therefore dispense with the organic solvents necessary for dissolving sheet rubber. The danger of fire and hygenic disadvantages are thus avoided. The latex sap normally contains about 40 per cent solids or *total solids*, as they are often termed. This sap may be concentrated by evaporation or by separating the water from the total solids by centrifugal force. The higher concentrations contain from 60 to 75 per cent total solids. It is this concentrated form which is generally used by the moulage worker for the making of rubber molds and casts. Where a less concentrated form of latex is desired, it is far more simple to dilute the concentrated latex with water than to increase its concentration by centrifuging. It is well worth-while to bear this fact in mind; for it is advantageous to buy latex in concentrated form and dilute it to suit specific purposes.

In molding and casting, the first application is sprayed or painted on the model in a comparatively thin state so that a good impression may be obtained of the finest details. After this first coat has been applied, a latex mixture in a more concentrated form, containing fillers such as cellucotton, wood flour, flour silica, clay, cork dust, or talc, is used to cover the first application. Sulphur and other agents used in vulcanizing may also be employed with the unvulcanized latex concentrate.

Highly filled mixes may be made and the latex compound applied to fabrics, models, casts and similar objects in a minimum of time. It has become more and more common to compound latex by adding fillers and curing ingredients in the form of a colloidal suspension in water. It is, therefore, of particular advantage in the case of concentrated latex that owing to its low water content this convenient method of compounding may be employed. This applies particularly when compounds with a rather high content of solids are desired, such as for spreading purposes in pastes or cements.

In the addition of ultra-accelerators there is no danger of scorching. As long as the rubber is in the form of a water dispersion, the action of accelerators is slow, even at a temperature of 100 C. (212 F.). A strong action takes place only when the latex is dried.

The unhealthy method of vulcanization with sulphur chloride should be replaced by the far superior method of heat vulcanization with the most active accelerators.

Owing to the elimination of mastication and the short period of

vulcanization necessary, a product is obtained from latex which has the greatest tensile strength and the best aging properties. The simplification of working methods facilitates control and makes calculations more reliable.

For those interested in the further study of rubber, the following books and pamphlets are recommended: *Rubber Latex;*[1] *Latex;*[2] *Latex and Its Industrial Application;*[3] *Latex in Industry;*[4] *Molding and Casting;*[5] *Facial and Body Prosthesis.*[6]

Rubber latex and vulcanized latex (Vultex) should not be confused, since they react differently when applied to the model. For example, the common latex has not been vulcanized and will stick to the model unless a separating medium, such as shellac or laquer, is used. Vulcanizing agents, accelerators, antioxidants and fillers must be added to this type of liquid rubber if the mold is to be kept for a period of years. If the mold is to be used only a few times and then thrown away, the vulcanizing agents and antioxidants may be omitted. However, fillers are necessary to give the rubber the proper consistency for application. Common latex sets more slowly than vulcanized latex, unless a coagulating agent such as magnesium sulfate or ammonium chloride is added. These should not exceed 1/100th of the total ingredients of the mixture, for they will cause it to coagulate or set before it can be applied.

In contrast to common latex, vulcanized latex does not stick to many objects. For example, it does not adhere to wet or dry plaster of Paris. In fact, the plaster absorbs some of the water from the vulcanized latex and causes it to set and dry more rapidly than common latex.

It is desirable in most applications of latex to add vulcanizing agents to the latex while in a liquid form, then cause the rubber to be deposited in the manner and by the means desired, after which the deposit is dried and subsequently vulcanized. However, it is possible to vulcanize the individual rubber particles while still suspended in the aqueous solution which also contains suitable vulcanizing agents. This is done by heat and pressure. After application this vulcanized latex needs only to dry and will not deteriorate readily or become syrupy as will unvulcanized rubber.

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[1] Stevens, H. P. and Stevens, W. H.: *Rubber Latex.* Rubber Growers Association, Inc., 2, 3, 4 Idol Lane, Eastcheap, London, E. C. 3 England, 1933. (Pamphlet)

[2] Hauser, E. A. and Kelly: *Latex.* Reinhart Publishing Co., 330 West 42nd Street, New York, N. Y., 1930. $4.00.

[3] Marchionna, Frederick: *Latex and Its Industrial Application.* Rubber Age, 250 West 57th Street, New York, N. Y., 1933. $15.00.

[4] Noble, Royce J.: *Latex in Industry.* The Rubber Age, 250 West 57th Street, New York, N. Y., 1935. $7.00

[5] Clarke, Carl D: *Molding and Casting.* The Standard Arts Press, Baltimore, Md., 1946.

[6] Clarke, Carl D.: *Facial and Body Prosthesis.* The C. V. Mosby Publishing Co., St. Louis, Mo., 1945.

The vulcanized latex is the most popular type of rubber for mold making. However, no one thing is perfect, therefore the property that makes vulcanized latex more valuable than unvulcanized latex for the making of molds also presents a difficulty. On drying, the vulcanized latex mold will lift from the model and create spaces between the mold and the model. To prevent this trouble it has been recommended that the rubber mixture be applied in small squares or strips with blank areas between. These should be allowed to dry before more rubber is applied in the same manner, with one square overlapping the one beneath. This may be satisfactory for small models, but the larger the model, and therefore the thicker must be the mold, the more lifting or pulling away in the depressed areas will result. This is caused by the shrinkage of the mold on drying. I have found that this can be prevented entirely by mixing common unvulcanized latex and vulcanized latex. In other words, the unvulcanized latex in the mixture acts as an adhesive to hold the mold to the model. If too much latex is added, difficulty will be experienced in removing the mold from the model; if too little is added, the mold will lift in the depressed areas or separate too readily. The worker must gain his own experience in this, as it is not logical to give set amounts of the two types of latex to use in formulas, since the object to be molded controls this proportion. For example, if a mold is to be made over a glazed terra cotta cast, the formula should contain a large amount of common latex in order to cause the mold to stick to the glazed surface which gives no absorption or "tooth" to hold the mold to the model while the rubber is drying and shrinking.

If an unglazed terra cotta cast is used as a model, the rubber formula should contain more vulcanized latex than is used on the glazed model, because an unglazed surface offers some absorbing properties to which the common latex may stick.

On a surface such as that offered by dry plaster of Paris, the rubber formula should have a high content of vulcanized latex and a low content of common latex. The dry plaster is quite absorbent and its microscopic porosity offers considerable "tooth" to hold the common latex.

Of course, vulcanizing and antioxidizing agents should be added to the common latex if such rubber molds are to be kept for a period of years. This is quite simple, since a stock mixture of these powdered ingredients can be made at one time and used as needed. These should contain the vulcanizers and antioxidents used for common latex. Just before the making of the mold small amounts of the powdered ingredients are mixed with the latex until the desired consistency is reached. The vulcanized latex can be mixed with a filler alone, such as cellucotton,

in a separate bowl; the vulcanized and nonvulcanized latex are then mixed together for application to the model.

THE ADVANTAGES OF RUBBER

Rubber is recommended in the making of the mold for the following reasons:

1. The rubber mold is more elastic and pliable than the agar or glue mold. It can be varied from a spongy softness to a tough, slightly resilient or nonbending product. The degree of pliability depends upon the ingredients of the formula. Air or gas can be introduced into liquid rubber (latex) by beating, as with an egg beater for small quantities, or by the introduction of an effervescent chemical during the mixing. The latex can be made hard or tough by adding large amounts of mineral fillers. However, the consistency most suitable for the average moulage for the cire perdue process may be obtained by mixing cellucotton (wood fiber) or wood flour with the latex. Sawdust will serve for this purpose for the outer rough layers of the large rubber mold.

2. The rubber mold is tough and will stand more rough treatment than the agar or glue mold, making it possible to obtain many more casts from a single mold. Only one or two good wax casts may be made in a single glue mold before the heat of the wax begins to have a detrimental effect on the details in the glue. Glue to which glycerin and dextrose have been added, and which has been tanned with two or three applications of 5% formaldehyde with a brush to the surface of the mold, can be used in similar fashion. Formaldehyde prevents surfoce melting; however, too much formaldehyde in the glue mixture prevents it from remelting and therefore causes it to be unsuitable for reuse. Scores of wax casts can be made from a single rubber mold. In other words, the rubber mold will endure much more heat than the glue mold. Even the heat created by the setting of plaster of Paris may ruin a glue mold if it is improperly compounded. To overcome this difficulty the plaster is generally mixed with ice water or the cast is removed from the glue mold before it has set to a point where heat is generated. These precautions are unnecessary when using a rubber mold, for heat up to 200 F. has the beneficial effect of vulcanization on a rubber mold, instead of harming it, as in the case of the glue mold. However, rubber becomes brittle from over acceleration under continued heat at 150-170 F. It also continues to contract unless properly compounded.

3. Rubber molds do not swell in setting as do glue molds, which will often expand a plaster mother mold to the point of breaking the bands holding it together. On drying, the glue mold shrinks tremendously in comparison with the rubber mold. Furthermore, a wax cast must

be removed from a glue mold within a few hours after the wax has been applied. Otherwise the glue will either stick to the wax or contract in shrinking to such an extent that the wax cast will be cracked or misshapen. This does not apply to the agar mold. The glue mold may be useless after drying twenty-four hours and become unsuitable for additional casts. To prevent this shrinkage caused by drying, it is advisable to incorporate glycerin, sorbitol, and other syrups such as molasses into the glue composition. However, a certain amount of water is necessary in the mixture either for use in compounding or to make the mixture flow properly into the details of the model. This water content eventually evaporates and causes shrinkage. The shrinkage is comparatively uniform, but there is enough to produce a distorted positive when the weight of the liquid casting material forces the glue mold into areas of the mother mold from which it has shrunk. Furthermore, a quantity of wax is poured into a closed mold to fill seams in the wax cast and increase the thickness of the wax in the lost wax process. If there is a shrinkage of the mold (whether agar, glue, or rubber) from the mother mold, the poured wax may run into the area between the mold and mother mold created by the shrinkage and cause considerable trouble. If the rubber mold is allowed to dry completely on the model, the shrinkage is negligible, even in large molds. Although a rubber mold may be removed from the model in twenty-four to forty-eight hours, it is best to wait longer for complete drying, before it is removed. If it must be removed in twenty-four hours, gentle heat may be applied to facilitate complete drying. This heat is important to fix the rubber dimension; an electric radiant heater (bathroom type) with a small fan can be used to speed up the drying. Small molds can be placed in a common cooking oven in which the temperature can be kept low.

4. Rubber compositions are more simple to compound and apply than glue or agar compositions, since they require no heat in the mixing or application. For example, a simple rubber formula would consist of Vultex No. H 235 mixed with cellucotton until it reaches the consistency of whipped cream. Such a formula is applied first to the model with a brush and later with a spatula. The mother mold is made after the rubber has dried (set) completely on the model. Hydrocal A-11 (U. S. Gypsum Co.) is recommended for the mother mold, because it does not expand in setting, whereas all plasters expand about .020 inch per foot and do not fit closely enought to the rubber.

In using glue mixtures, clay ribbons are applied over the plaster object to the thickness desired for the glue. (See illustrations). The mother mold or case is then made. After setting, the mother mold is removed, the clay ribbons are taken away and the model is washed.

The mother mold is replaced and the hot glue is poured to fill the space that was occupied by the clay. An agar mold is made in the same manner.

In making an agar or glue mold for the cire perdue process the original work in clay is generally cast in plaster first. This requires a plaster waste mold from which the plaster cast is made. It is possible that some of the detail and spirit of the original clay may be lost during these reproductive processes. In other words, reproduction from clay to the plaster negative, to the plaster positive, to the glue negative, to the wax positive, to the plaster-silica negative, and to the metal positive constitutes six definite duplicating processes, negative and positive, before the final metal cast is made. With a rubber composition the final metal cast may be obtained by passing through only four definite steps, namely, from the original clay to the rubber negative, to the wax positive, to the plaster-silica negative, and then to the metal positive.

To make a rubber mold from a clay original or model, iron (not brass) tins are inserted into the clay to form the line of separation, as in waste molding. (See Waste Molds in *Molding and Casting*).[1] The liquid latex is then painted on with a soft brush or sprayed onto the clay with an insecticide sprayer or painter's spray air gun. If the rubber is applied with a stiff brush, the details in the clay may be destroyed by the brush strokes on contact of the stiff bristles with the soft clay. After the liquid latex is sprayed on the clay it is allowed to set or dry to a consistency that will stand brushing. The latex is then mixed with cellucotton, wood, or cork flour, or sawdust, depending on the size of the model until the consistency of whipped cream is reached. This mixture is then brushed on top of the first coat. After this dries or sets, additional coats are added until the mold has attained sufficient thickness, which also depends entirely on the size of the cast.

5. The cost of the ingredients for making a rubber mold is less than for the ingredients to make a glue mold and considerably less than for the ingredients to make an agar mold. However, the rubber cannot be used over and over again as is possible with both glue and agar. This is a negligible factor when the time required to make the molds is considered. Moreover, the rubber molds may be filed away for future use, whereas the glue and agar molds must be remade after a short period of time.

Another angle to be considered is the fact that about three times as much glue or agar composition as rubber mixture is required for making a mold of a single object, because rubber is considerably stronger than glue, therefore, less need be used. This feature of rubber is the most

[1] Clarke, Carl D.: *Molding and Casting*. The Standard Arts Press, Baltimore, Md., 1946.

outstanding advantage. It permits a depth of detail not obtainable in other one-piece mold construction.

6. Fewer pieces are required for making a rubber piece mold than for a glue piece mold. The rubber is thinner and can be removed from the original as well as the cast wtih less effort, since it permits more bending. In fact, the rubber pieces can be folded back upon themselves. This is impossible with a thick, large, glue or agar mold. If an area of an agar mold is folded back upon itself, it will crack open.

DIRECTIONS FOR MIXING RUBBER MOLDING FORMULAS

The required amount of the mixed liquid ingredients should be placed in an enamel, glass, or crockery bowl. (Copper and brass bowls should not be used.) To these is added a small quantity of the necessary amount of mixed powders or fillers; the whole is then stirred until the powders or fillers are thoroughly incorporated. More filler is added and the mixture is again stirred until it is thoroughly mixed. This is repeated several times until the desired consistency is reached. The amount of the filler added varies according to the concentration of the latex and the purpose for which it is to be used. Larger quantities of cellucotton and sawdust may be used than such powdered materials as clay.

The first application of the mixture should not be so thick as to prevent it from being forced with a brush into the finest details of the object that is being molded. After the first application to the model or cast has dried, more filler may be added to produce the stiffness needed for remaining on a vertical surface.

It is not necessary to mix the entire amount of the rubber materials required to cover a given surface at one time as is essential in glue or agar molding. When a large mold is to be made the mixing may be done in small amounts at different times. This method prevents the waste of materials caused by mixing more than is necessary for immediate use.

The secret of success in using rubber molding materials is *thorough and careful mixing* and allowing sufficient time for complete drying.

THE NECESSARY RUBBER INGREDIENTS AND THE AMOUNT TO USE

Owing to the tremendous strength and indestructibility of rubber molds it is necessary to use only about one-third of the amount of material one would use in making a glue mold. In using rubber molding materials, the filler ingredients are stirred into the liquid ingredients.

Approximately one pint of the concentrated liquid ingredients or paste is required in the final preparation to cover completely (by spreading) one-half of a model or cast that is twelve inches high and six inches wide. The resulting mixture or final application should have the consistency of stiff paste or whipped cream, depending on the work in mind.

By the use of a common egg beater, air can be whipped into the rubber mixture, thereby increasing its bulk and the flexibility of the dried rubber mold. This is helpful where only small amounts of air are whipped into the rubber latex mixture. However, its bulk can be increased as much as eight times by beating air into the mixture. This produces a mold that is often too flexible. Furthermore, unless a metallic salt is incorporated into the mix and thorough vulcanization employed large air bubbles will be compressed together in removing the mold from the model. These bubbles remain stuck, thereby distorting the shape of the mold. The amount of filler may vary according to the amount of water in the latex. The more water, the longer it takes to dry and set, and the more shrinkage will take place. A latex having 60 per cent total solids seems best for the purpose. The more filler used, the stiffer the mold becomes. All of these factors may be varied if the worker thoroughly understands the technique of making the mold under varying conditions. In other words, he can make many mixtures work satisfactorily just as soon as he "gets the feel" of the materials he is using and knows how to proceed. Too much filler causes the rubber mixture to congeal before it can be applied. Such a rubber mixture is for air drying and should not be poured into a closed mold.

It is probable that after one has made a successful rubber mold, he will not return to the antiquated methods of glue molding, especially in cases requiring many casts.

DIRECTIONS FOR MAKING A RUBBER RELIEF MOLD

If the unvulcanized latex mold is applied to a porous model such as a plaster cast, the mold must be vulcanized and dried on the model by the use of heat before it will separate. By the use of vulcanized latex this difficulty of sticking can be overcome. In fact it may be overcome to too great an extent; for it is quite common for a vulcanized latex mold to lift from depressions on plaster casts giving distorted impressions. I have overcome this difficulty by mixing a certain amount of unvulcanized latex with vulcanized latex purely to gain some of the adhesive quality of the unvulcanized latex and to hold it long enough for the rubber mixture to dry thoroughly. The novice will experience these difficulties as he comes to them; nevertheless it is better to know how to overcome the difficulty when it arises.

Figure 5. A clay model of a portrait relief.

For the beginner the simplest method of making a rubber mold is as follows: Naturally he should choose a small relief model such as a plaster medallion for his first attempts so that he will have only one side to mold. He proceeds as follows: A small quantity of vulcanized latex (Vultex No. H-235 or F-293*) is poured in a crockery, glass, or enameled bowl. A bristle brush is dampened and rubbed well with soap and excess soap is squeezed out of the bristles. This is done to prevent the rubber from coagulating and sticking to the brush, thereby ruining it. This brush is dipped in the latex and the model is given a coat of liquid latex to obtain an impression of the finest details. After this the brush is washed in cold water. The first coat will dry in about ten minutes becoming transparent as it dries. Small pieces of cellu-

* General Latex and Chemical Co., Cambridge, Mass.

Figure 6. The rubber latex is sprayed on the clay model. However, if considerable care is taken. the first coat can be applied with a soft brush. After this has dried a heavier coat containing cellucotton filler may be applied with a brush.

cotton or a small amount of wood flour are then stirred into the latex mixture that remains with a steel spatula or table knife until the mixture becomes a paste. This paste should be stiff enough to remain on a vertical surface without running. If too little cellucotton or wood flour is added, the mold will take some time to dry. If too much is added, in the illustrations. The mold thus formed is allowed to dry which should take about twelve hours. After the mold is dry it may be stripped from the model by simply bending it from the surface. Small rubber relief molds do not require mother molds. However, it is best to make mother molds for the large relief molds. This is done by first coating the rubber mold with caster oil or petroleum jelly and then applying

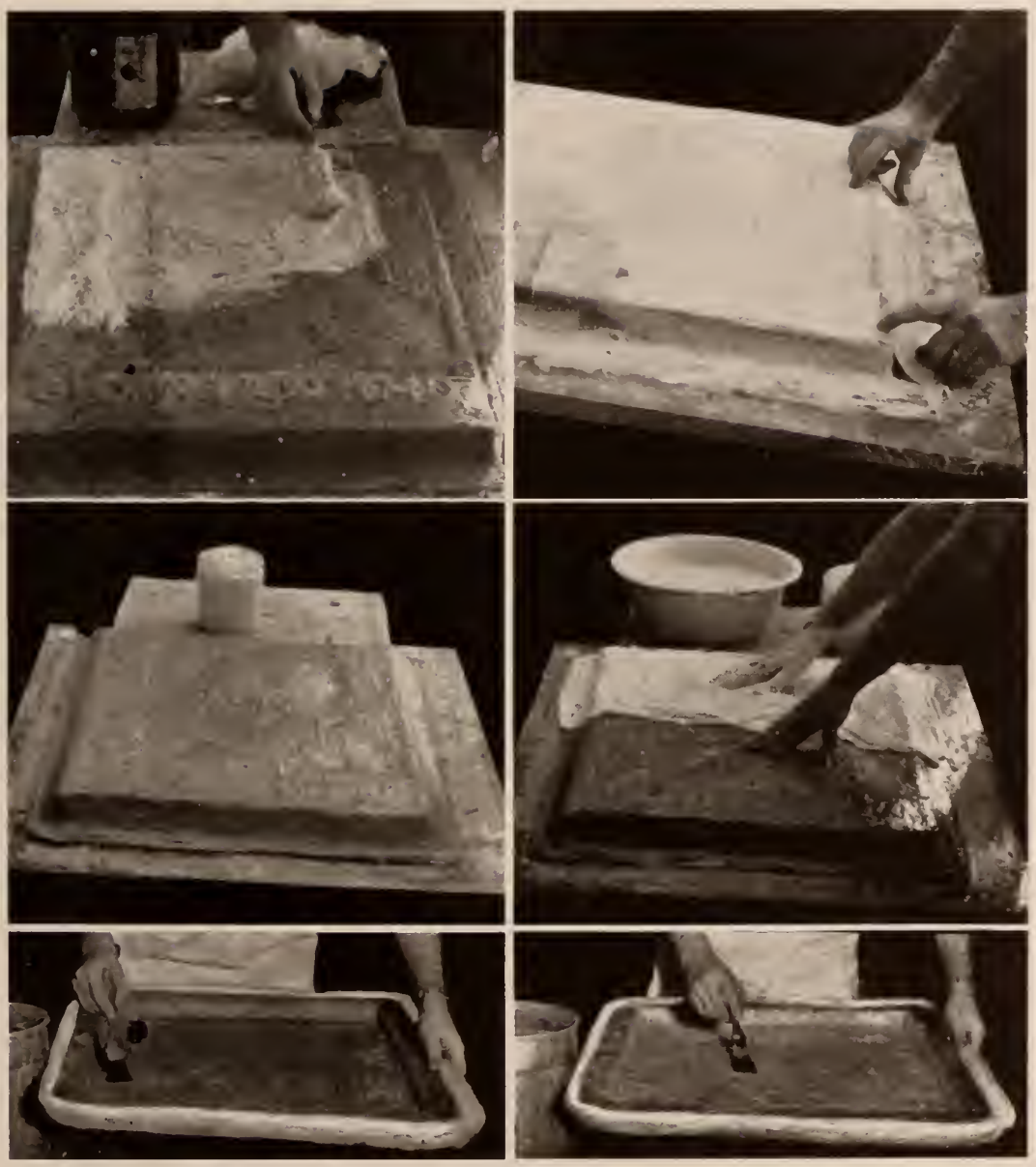

Figure 7. The rubber relief mold. *a,* Succeeding coats of latex and filler are applied. Complete drying is allowed to take place between coats. *b,* To create hollow areas to relieve the mother mold easily from the mold a piece of gauze is placed from undercut areas to the base. These are then covered with latex and filler. *c,* Petroleum jelly as a separating medium is applied before making the mother mold. *d,* The plaster mother mold is then made. *e,* Before making the wax cast, a solution of soap or glycerin is applied as a separating medium. *f,* The wax is painted into the rubber mold.

air pockets will result between the first coat of latex and the paste. Furthermore, an excessive amount of cellucotton or wood flour will cause the latex to coagulate, making it unsuitable for further use. When this paste is stiff enough to remain on a vertical surface, it is simply spread over the first coat of latex with the spatula or table knife to a thickness between one-eighth and one-fourth of an inch. It is also

Figure 8. The rubber mold from the clay model.

advisable to reinforce the rubber mold with strips of gauze as shown a plaster of Paris-water mixture to form the shell while the rubber mold is still on the model.

Plaster casts may be made from the rubber mold by first coating the rubber mold with a separating medium of equal parts of alcohol and castor oil. For wax casts a soap separating medium or equal parts of glycerin and water are used.

DIRECTIONS FOR MAKING A RUBBER MOLD OF A ROUND SUBJECT

The line of separation is determined and may be marked on the cast with a pencil. While clay and plasteline models may be molded with rubber molding materials, it is advisable first to experiment on a harder surface such as plaster, metal or terra cotta.

The cast is painted with shellac and allowed to dry if unvulcanized latex is to be used. It is then imbedded in clay up to the line of separation. This may be done with ribbons of clay previously rolled flat. A funnel shaped piece of clay is added at the base of the model to provide an opening in the mold for pouring the positive. If the original model has been made of clay or plasteline, tins may be inserted along the line of separation as in making a waste plaster mold. These tins take the place of a clay wall that is built around a plaster cast, as seen in the illustration. Under no conditions must these tins be composed of copper or brass. No separating medium is necessary if vulcanized latex is used or if the unvulcanized latex contains a vulcanizing ingredient and the mold is vulcanized by heat before removiing it from the model. The first coat of latex should also be sprayed on with a hand spray gun similar to those used with insecticides, or a power driven air brush. However, it can be applied with a soft brush if care is taken not to scratch the surface of the clay or plasteline. This first coat is allowed to dry before applying a second coat.

Registration grooves or depressions for perfectly fitting the two halves of the final rubber mold together are cut into the clay wall. If the original model is of clay or plasteline and tins are used along the line of separation, registeration points may be made as follows: Small balls of clay or plasteline are prepared by rolling them between the palms of the hands. These balls are cut in half and the halves placed on the tins at advantageous points close to the model.

A thin mixture containing only a small amount of filler is worked into all crevices of the cast with a varnish brush. Before using the brush with latex, it should be worked up with soap to a thick mass of soap

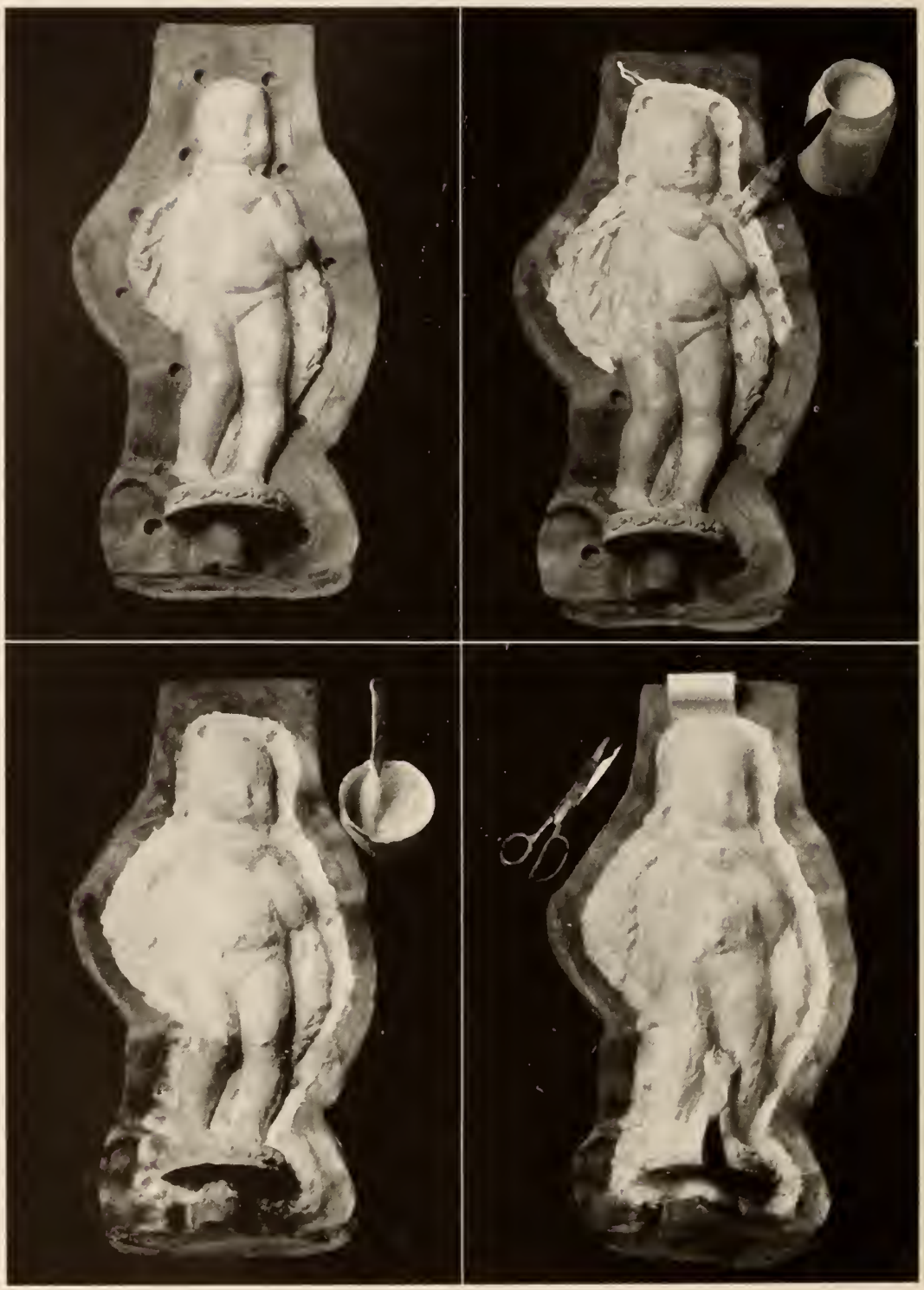

Figure 9. The rubber mold of a round subject. *a*, A clay wall is built up around the model along the best lines of separation. Registration notches are bored into the clay wall. A line is scratched into the clay to represent the extent of the area to be covered by rubber. *b*, A thin latex mixture is applied. This is allowed to dry. *c*, A filled or thick mixture is applied. *d*, This coat is reinforced with gauze.

Figure 10. *a*, The gauze is reinforced with another layer of rubber. *b*, After drying, the surface is pushed down with the straw ends of a whisk broom to be sure that no air areas are left between the layers of rubber. These will stick together even in the dry rubber. *c*, The rough edges of the rubber are cut away with scissors or a razor blade. *d*, The plaster mother mold is applied.

suds. These suds should then be wiped off on a dry towel and a thin layer of soap left on the bristles. This prevents the latex from sticking to the brush. After it is used, the brush should be washed in cold water immediately, otherwise the rubber will set and the brush will not be fit for further use on the mold. This thin mold is then allowed to stand until it has set. More filler is added to additional liquid until the mixture is thick enough to remain on a vertical surface without running off. The fingers or a spatula may be used for the final application, which should be of a uniform thickness of one-eighth to one-half inch according to the size of the mold. This is allowed to set for a period of twelve to forty-eight hours, depending upon the thickness of the mold and the temperature of the room. If the mold is placed on a hot radiator, in the sun or in an oven, setting takes place in less time. A rubber mold will stand temperatures up to 100 C. (212 F.) without being injured. Gentle heat only should be used where there is a possibility of damaging the model.

Additional registration grooves are cut in the clay for the case or mother mold. After setting, the rubber mold is painted with castor oil, petroleum jelly, shellac or lacquer.

Half of the case or mother mold is prepared over the rubber mold in plaster of Paris.

For the preparation of the other halves of the mold and case, the first halves are turned over and the clay wall is removed, with the exception of the funnel-shaped piece of clay at the base. The edges of the first halves of the rubber mold and the case should be painted with castor oil, petroleum jelly, lacquer or shellac before proceeding to make the opposite halves. If tins were used on a clay or plasteline model, these should be removed before the opposite halves are made.

The rubber mixture is then applied on the other side of the model or cast in the same manner mentioned above and allowed to dry or set.

The second half of the case or mother mold is prepared in plaster of Paris.

After the second half of the mother mold has set, the two halves are separated. The rubber mold is stretched away from the model. However, this cannot be done until the rubber mold has completely set and is dry, otherwise the rubber will be distorted.

The positive is made in the usual manner by priming or filling both halves while the mold is open, then closing the mold, tying the halves together with wire and pouring the positive material to fill the seam or space between the two halves of the positive. The entire posi-

Figure 11. *a,* The mold is turned over to rest on the mother mold and the clay wall is removed. *b,* A petroleum jelly or shellac separating medium is applied. *c,* A thin coat of latex is applied and allowed to dry. *d,* The reverse side of the model is built up with a latex-cellucotton filler mixture and reinforced with gauze.

Figure 12. *a,* The completed second half of the rubber mold. *b,* The excess edge is cut away. *c,* A separating medium is applied. *d,* The second half of the mother mold is made in plaster. *e,* The edges of the mother mold are scraped to expose the join line. *f,* A screw driver is inserted in the join line to open the mold. *g,* The model is removed. *h,* The model, component parts of the rubber mold and the mother mold.

tive may also be made by pouring the positive material into the closed mold through the funnel-shaped opening at the base. Easy separation is obtained if a very thin coating of soap is applied to the rubber mold before making the first few positives. After two or three casts have been made in a rubber mold, a separating medium is no longer necessary. Shellac may also be used for this purpose but soap serves as well for plaster or wax impressions in rubber molds and is less expensive to use. The case or mother mold is usually shellacked both inside and out to prevent the waste positive material from sticking to it. However, this is not absolutely necessary when a few casts are to be made.

CHAPTER VII

RESILIENT PLASTIC MOLDS

Definition: The term *plastic* has come to have a variety of meanings. In fact, the meanings are so numerous that it becomes necessary to classify and condense them into confines of molding usage. The Latin word *plasticus* was taken from the Greek *plastikos* and used by the French as *plassein*, and the English as *plastic*. Its first meaning was to *form* or *mold*. From it are derived such words as *plaster*, *plasticize*, *plastodynamia*, and many others.

Among the meanings of the word *plastic* are:

1. Giving form or fashion to a mass; formation.

2. Causing or directing production or development; creative; as the *plastic* force of nature; *plastic* imagination.

3. Capable of being molded or modeled, as clay or plaster; hence, pliable; impressionable.

4. Characterized by modeling; also, giving the effect of that which is modeled or sculptured; as *plastic* dancing.

5. In biology and surgery the word *plastic* may be used to express that which is capable of undergoing metabolic transformation; formative; hence, pertaining to the growth, repair and transformation of tissues, as *plastic* lymph, *plastic* surgery; also, capable of structural adaption to changing environment; as a *plastic* race, genus.

6. In physics the term is used when expressing capability of being deformed continuously and permanently in any direction without rupture, under a stress exceeding the yield value.

In the plastic manufacturing industry, the term has a variety of meanings. For example, a plastic can be the material used or the product produced. It can mean the extent of bendability, softness, hardness or fluidity of the material or the product. For example, a house paint is made more *plastic* or fluid by thinning. The term *resilient* is also at times interchangeable with *plastic*. However, it generally means the ability of rebounding or springing back into a previous form.

Basicly, the plastic industry is a branch of chemistry. One simplified but broad version of the origin of plastics is that they are derived from "coal, air, lime and water". If four more basic natural substances are added—petroleum, cellulose, sulphur, and salt—nearly all of the commercial types of plastics can be accounted for. Naturally, these basic materials must be subjected to numerous chemical changes before the resulting plastic is produced.

The first step in the manufacture of plastics is the synthesis of a large group of simple chemicals, such as ammonia, acetylene and hy-

drochloric acid. From these the various reactive ingredients are synthesized. The manner in which these latter ingredients are combined to produce the final product varies with the type of resin. In general, resins are either condensation type (i. e. phenolic resins) which result from the combination of dissimilar organic chemicals to produce a new compound, or polymerization resins, (i. e. vinyl or acrylic) which result from a linking together of like molecules of the monomer to produce a resin of the same chemical nature but with different physical properties, called the polymer.

For the sake of convenience in discussing their preparation and properties, three categories of plastics are recognized. They are (1) *thermosetting* resins, (2) *thermoplastic* resins, and (3) *cellulose* derivitives.

Thermosetting materials are those which harden when heat is applied. They must be formed relatively quickly in order to attain the desired shape before they become rigid. The five types of thermosetting resins are: 1. Phenolic; 2. Urea; 3. Melamine; 4. Silicon; and 5. Unsaturated Polyester Resins.

Thermoplastic materials are those which can be repeatedly softened by heat and hardened by cooling. No chemical reaction is involved in the shaping of thermoplastic resins. This group of resins is comprised essentially of seven types. They are: 1. Nylon; 2. Alkyd; 3. Polyethylene; 4. Styrene; 5. Acrylic; 6. Vinyl; and 7. Coumarone.

Cellulose Derivitives in general are thermoplastic in their behavior towards heat. There are a variety of cellulose esters and ethers generally classified in the following five types: 1. Nitrate; 2. Acetate; 3. Butyrate; 4. Ethyl; and 5. Regenerated Cellulose.

Nearly all of the thermosetting, thermoplastic and cellulose plastics in one form or another are of use in mold making. Furthermore, their possibilities in the future are unlimited. New materials, or different applications of old materials are suggesting themselves in such rapid succession that by the time this book comes off the press, this chapter will be "old stuff".

Although thermosetting resins may have a limited use in mold making, those which are presently available do not lend themselves very well to this application; consequently, we shall be concerned purely with the thermoplastic resins. Of this type, the *acrylic* and *vinyl* resins are the most popular.

Acrylic resins: The best known member of this group is methyl methacrylate, which is readily malleable, relatively strong and light in weight. Resins of this type are made from methyl and ethyl alcohols, acetone, hydrocyanic acid, and similar chemicals. The reactions involved in the synthesis of the intermediate compounds are somewhat complicated.

Vinyl resins: Vinyl derivatives are basically those produced by the substitution of one of the hydrogens in etheylene by some other group. Thus, the vinyl radical is $H_2C{=}CH{-}$. When a hydroxyl group replaces the hydrogen, the compound is vinyl alcohol. Analogously, the compound containing chlorine is vinyl chloride, and the compound containing an acetyl group is vinyl acetate. These are the three industrially significant vinyl derivatives. They are translucent, easily colored, and readily plasticized into soft, pliable, resilient resins, which adapt themselves admirably to mold making. A copolymer of vinyl chloride and vinyl acetate is also an important material for this. Derivitives known as polyvinyl acetals are produced by the reaction of aldhydes with polyvinyl alcohol; polyvinyl butyral made with butyraldhyde may be applied as a coating to fabrics. Another resin related to this group is polyvinylidene chloride, best known for its chemical inertness and its resistence to wear. Polyvinyl chloride is the newest available dispersing resin giving a more resistent and tougher end product. The vinylidene radical is $H_2C = C$, i. e. ethylene in which two hydrogens of one of the carbon atoms have been replaced by other elements or groups.

Coumarone resins: These range from viscous liquids to high melting solids. Coumarone and indene obtained from coal tar are copolymerized in their production.

The great bulk of the products produced by the plastics manufacturers consist of molding powders. These powders are utilized commercially in the fabrication of all the familiar plastic items in every day use. However, this fabrication involves the use of elaborate equipment which compresses the heat-softened molding powder into molds under intense pressure. To withstand this pressure, the mold must be made of high quality, hardened steel, and is consequently very expensive. This procedure is practical only where a great number of identical items are to be produced.

In seeking plastic materials suitable for the small scale production of molds, we are restricted to those which may be fabricated under laboratory conditions or in small shops without utilizing high molding pressure or extremes of temperature. Although there are a number of liquid casting resins on the market, these are for the most part thermosetting resins of the phenolic types, which are rigid. Consequently, of the broad field of plastics, we are limited to a very few.

The acrylic resins, of which the most important is methyl methacrylate, may be plasticized by mixing the polymer, ground to powder form, with the liquid monomer. The resulting dough may be compressed into molds and heat cured to yield a homogeneous product. The resulting material is rigid; the liquid monomer acts as a temporary plasticizer and does not impart a permanent flexibility to the acrylic.

The most suitable plastics for mold making are those of the vinyl

type. These may be combined with certain plasticizing agents, which give them a lasting flexibility without sacrificing too much tensile strength. Chemically the molecules of the plasticizer become interposed between the molecules of the resin polymer and thus provide flexible links in the otherwise rigid polymer chain of molecules. As plasticizing agents, a great number of substances may be used, usually of an oily nature. Among the most efficient for the vinyl resins are dioctyl phthalate, dibutyl sebacate, triethylene glycol, and derivatives of ricinoleic phosphoric sebacic or phthallic acids. However, for best results, the plasticizer must be intimately combined with the resin as a part of the manufacturing process. There are several plasticized vinyl dispersions on the market which may be used. One such material, called Plastisol, is manufactured by the Bakelite Corporation, primarily for electrical insulation; however, the clear or transparent grade resilient resin is suitable. It consists of a suspension of Vinylite resin in a suitable plasticizer and comes in the form of a semi-liquid or paste. The viscosity may be lowered by adding more plasticizer (this also increases the flexibility in the cured product at the expense of tensile strength.) Upon heating to approximately 130 C. (266 F.) the material cures by fusion of the ingredients.

Another product that has proved very successful is sold under the trade name of Elastomer No. 105.* This material, which is shipped in liquid form has consideralbe elasticity, resembling rubber in this respect. It has more elasticity than Plastisol and can be cured at lower temperatures. Elastomer is a viscous material with a 100 per cent solid content, which will cure and polymerize by the simple application of heat without pressure. It does not shrink or expand materially during the curing process and will take the finest details of the pattern, including gloss. While it resembles rubber in many characteristics, it is unusual in its resistence to most solvents, including aromatic hydrocarbons, oils, acids, alkalies, and water. It does not oxidize and harden on aging. It retains its flexibility even at extremely low temperatures, nor does it sustain a flame. It can be cured at lower temperatures than most plastics, which is advantageous.

Elastomer No. 105 is essentially a novel, flexible mold material. The flexibility of the finished molds makes possible their use in casting objects with undercuts.

The recommended procedure in the making of flexible relief molds for the casting of waxes, phenolic resins, plaster, etc., is as follows:

The master or pattern pieces are fastened to the bottom of a shallow pan, preferably by placing them in a paper-thin layer of Elastomer No. 105, and curing for five minutes at 220 F. (104.4 C.) By this method the use of glues is avoided, which was found unsatisfactory

* Elastomer No. 105, Electro-Technical Products Division, Sun Chemical Corporation, Nutley, New Jersey.

because solvents or moisture might be entrapped underneath the patterns. These will try to escape when heat is applied during the curing process of the mold. The mold assembly is removed from the oven and filled while still hot between 150 F. (65.5 C.) and 175 F. (79.4 C.) with Elastomer No. 105 until the highest point of the master is covered with a layer at least ¼ inch thick. Pouring the Elastomer over the preheated master assembly will not only avoid formation of air bubbles in the mold but also effect a bond of the mass of the Elastomer to the previously cast thin film in the bottom of the mold.

The mold is then placed in an oven at a constant temperature between 93.3 C. and 115.5 C. (200 and 240 F.) for ten minutes for each quarter-of-an-inch thickness of the mold. This will set the mass to a tough rubber elastic state. The mold is then chilled in cold water in order to cool out. The pattern pieces can then be removed by trimming the first layer of mold material.

To increase the life of the molds, care should be taken that they are thoroughly cooled in either air or cold water before removing the cast pieces. Should a mold lubricant be required, no mineral or vegetable oil should be used as these will affect the life of the mold. Special mold lubricant will be furnished upon request by the manufacturers of Elastomer. However, soap or glycerine are good separating mediums for use with many plastisols.

If the flexible molds are to be used for the casting of polyester type resins, the mold making procedure is the same as outlined above. However, the manufacturer's experimental mold lubricant PE-17 can be used for these resins. This material is not as yet in actual production but samples and price may be obtained upon request. It is further recommended to cure the polyester resins only to the gel stage in which they may be removed from the mold and then fully polymerized. Elastomer No. 105 will impart a slightly yellowing haze to water clear resin castings. This surface discoloration will lessen with each subsequent casting. It may be removed by a slight buffing operation.

When it is desired to have plastisol molds more flexible, they can be made as thin layers between which are placed a foaming plastic. They can also be left as thin, non-foaming molds which are well supported with mother molds. In the latter case, the surface of the plastic that comes in contact with the mother mold must be comparatively free of undercuts. The manufacturers are now producing foaming plastic which can be supplied on demand. Foaming agents such as alcohol and sodium bicarbonate, sodium fluosilicate, Unicel (Dupont) can also be incorporated into the plastic. Higher or lower degree of volume increase, and larger or smaller cell sizes can be obtained by varying the amount of foaming agent.

Electro-Technical Products Division of the Sun Chemical Corpora-

tion recommend that their foam material be used at an optimum temperature of between 80 C. (176 F.) and 90 C. (194 F.). The time required for foaming at these temperatures varies from a few seconds to several minutes, depending on the volume of the foam shape. The end of the foam period can easily be determined visually. The foam shape is then subsequently heated up to about 110 C. (230 F.) to insure proper cure of the cellular structure.

At the present the shelf life of most plastisols is only a few months. However, this can be increased by refrigeration; and Elastomer No. 105 is stable at room temperatures for over one year.

The Electro-Technical Products Division of the Sun Chemical Corporation at present is producing the best plastisol for mold making, because of its elasticity. Furthermore, their product is being improved in tensile and tear strength.

CHAPTER VIII
THE ROMAN JOINT

In large pieces of sculpture it becomes essential to divide them into component parts for ease of molding, casting, handling and erection. Each part is made separately and finally pieced together before or during erection. This must all be taken into account before a large work of art is cast, even in the plaster stage. However, the real divisions are generally made when the work has been finished in the plaster stage. For example, consider a large equestrian bronze statue to be erected in a park or on a wide avenue. The horse may be made in two or more pieces and even the rider may be composed of two or more sections. This all depends on the size and mechanical construction of the figures involved. While large sculptures are generally made in large studios, the problem arises of moving them to adequate foundries. To do this they must be cut into pieces. The cut ends of the section are made so they will fit back together in perfect registration. This is done by preparing Roman joints at the junction of two pieces. It is generally advantageous for the foundry to mold and cast large sculptures in sections because it is more simple to make and pour small molds than large ones. Furthermore, the possibility of error is minimized. While bronzes may be cut and welded back together, it is invariably more satisfactory to make Roman joints while the work is in the plaster stage.

The simplest idea of a Roman joint may be conceived by considering the type of children's picture blocks in which one block fits into another, each being slightly smaller than the preceeding one. To form such a joint on a plaster cast, the cast must be studied to consider the most convenient and logical place for the join line. For example, a standing soldier could be divided at his belt line; for that would divide the body in fairly equal parts and the resulting join line would be easy to hide. In the same manner, a large head could be divided from the body at the juncture of the collar. Once this line of separation is determined, the plaster cast is simply sawed in two along the line.

In considering the life size nude female in Figure 13, it was decided to divide the plaster cast at the hips. The steps in forming the Roman joint at this piont will be described as follows.

In Figure 13a the lower half of the hollow plaster cast is represented. The hollow opening was simply stuffed with crumpled newspaper until it was considered that this paper would bear the weight of a small amount of gypsum cement. The plaster and water were mixed and simply applied to the paper. As it began to set up, it was shaped with a spatula into flat surfaces and angles as seen in Figure 13b. This

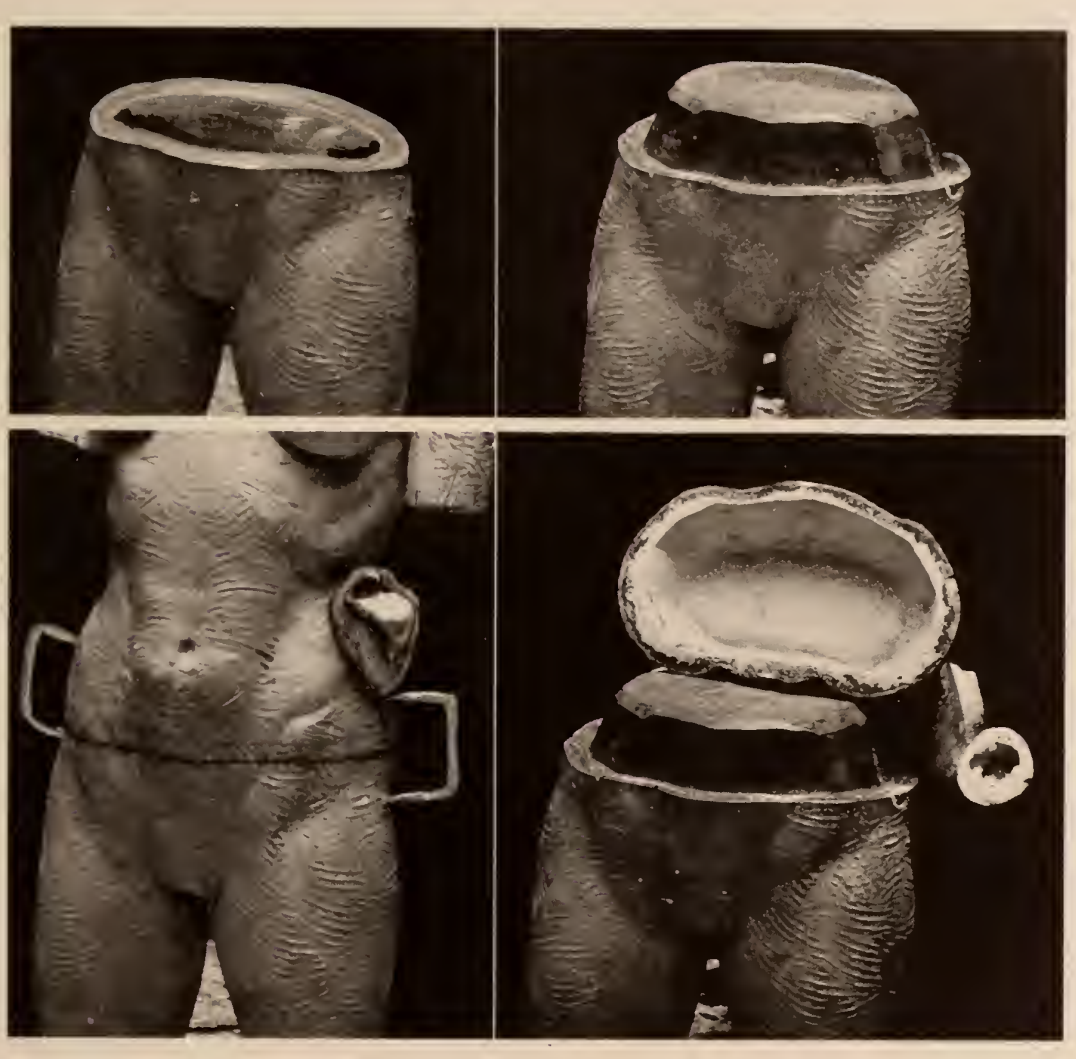

Figure 13. The Roman joint. *a*, The bottom half of a life-sized hollow plaster figure. *b*, The built up lower section of the Roman joint. *c*, The two sections clamped together with a clay funnel in place. The plaster has been poured. *d*, The two sections of the Roman joint completed.

projecting area must be kept small enough to fit within the upper part of the hollow plaster cast when it is placed back upon the leg part.

After the projection part has been made and smoothed off so that there are no under cuts, it is well shellacked. After this dries, it is given a thin coat of oil as a further means of separation. A hole three quarters of an inch is then drilled in the top half a few inches above the area that will project into the top hollow. The plaster dust created by this drilling is cleaned from the cast. This hole is made for convenience in pouring a thin liquid plaster-water mixture to form the top half of the Roman joint.

The top half of the body is then placed on the lower part and made to register perfectly. Clamps are then driven into the cast so that

the two halves cannot get out of position. Then clay is used to form a cup or funnel around the drilled hole on the side of the piece of sculpture. (Figure 13c.). A metal or plastic funnel having a bent neck can also be used for this purpose instead of the clay cup. This cup or funnel is so placed as to direct liquid gypsum cement into the hole, as seen in Figure 13 *d*. This must be poured as a watery thin mixture; otherwise its flowing propertites are reduced and the surface will not be covered. After the plaster has set, the two halves of the sculpture may be separated for more convenient metal molding and casting. The final bronze pieces will generally fit together in perfect registration. The join line can be lost in the final finishing and coloring of the metal.

CHAPTER IX

THE POURED MOLD

In making a poured mold, one generally thinks of using glue or agar. While both are satisfactory, agar is undoubtedly better and is used more often. This is because agar compositions do not melt until they reach the boiling point of water, or 100 C. Therefore they are more resistant to hot wax-resin mixtures. These are painted and poured into the mold to form the wax cast or impression that is used in the cire perdue process.

Rubber and resilient plastics may also be poured into closed mother molds. Where rubber or plastisol plastics are used, the mold is made much thinner than when using glue or agar. This is possible because rubber and the plastics have many times the strength of glue or agar. Furthermore, rubber does not set as do glue and agar but must coagulate or dry as a result of the plaster cast and mother mold absorbing water from the rubber composition. However, coagulating agents may be incorporated in the rubber to cause it to set chemically or to coagulate. This is not actual drying, because after coagulation the rubber still contains considerable free water which should evaporate by drying. Nevertheless, a coagulated rubber mold can be handled, with care, after it has coagulated and before it has dried. In any event it should be thoroughly dry before the wax-resin mixture is painted into it. Otherwise considerable shrinkage takes place on drying. Therefore, rubber molds, whether prepared by spreading or pouring should be thoroughly dried while still in place on the model to prevent shrinkage. In the spreading process this generally takes place without the addition of heat because the outer surfaces of the mold are exposed to the air. In the poured process it invariably becomes necessary to heat the combined mold, mother mold and pattern with gentle heat until they are thoroughly dry before removing the mold from the pattern. Otherwise shrinkage takes place.

Resilient plastic molds are set in similar fashion by the application of heat.

Agar compositions are more satisfactory for making molds for the lost wax process than glue. However, glue may be used if considerable care is taken in applying the hot wax of the positive to the glue surface. In any event the directions for making a glue or rubber mold would be identical, with few exceptions, to the following directions for making an agar mold.

Most agar compositions do not adhere as readily as glue to the average model. However, the agar composition used for the cire perdue pro-

Figure 34. *A*, Bricks or wooden blocks are placed around the model to support a wall. *B*, Thin plywood is used to form the wall. *C*, Open areas at the top between the legs are packed with clay. A clay smooth is also applied to the area around the model to fill the spaces between the wood wall and the model.

cess contains a considerable amount of glycerin and similar syrups such as sorbitol (*arlex*), which are absorbed without difficulty by porous models. This may cause the model to stick to the mold. Some of the syrups will be lost from the agar composition unless the model is made nonabsorptive by the use of a separating medium, for example, shellac or lacquer.

The following directions apply to models made of rigid materials such as plaster of Paris, wood, metal, stone, terra cotta, oxychloride-cement mixtures, and similar compositions. They do not apply to models composed of water-clay or plasteline. These must be treated in an entirely different manner, as explained elsewhere in the text. Plaster and stone-like materials require one or more separating mediums, such as the application of shellac or oil, or both.

A separating medium is of the utmost importance if glue or gelatin is used for making the mold over practically any material. Shellac is generally used for the purpose of obtaining good separation, although a lacquer may be employed. One of the advantages of lacquer over shellac is that most lacquers dry more rapidly than shellac does. In either case the model should receive two coats of shellac or lacquer. When these are thoroughly dry, a coat of mineral oil or vegetable oil is applied and worked into every detail with a bristle brush. The model may then be placed horizontally, as seen in Figure 14 *a*.* Bricks, pieces of wood chunks of clay and similar materials may be employed to create supports for a wall or as a means of obtaining the separation of two or more pieces of the agar or glue mold. These supports should naturally follow the line or area of separation as closely as possible. (See Figure 14 *c*.)

Thin boards are then placed on these supports as near as possible to the line of separation. These boards are cut into the proper shapes with a band, jig, or arbor saw. Seldom are the measurements absolutely accurate, since they are visualized only. When the boards approximately fit, as seen in Figure 14 *b*, cylindrical clay strips are placed on the board next to the model, as shown in Figure 14 *c*. These strips are used to fill the space around the model beween the boards and the model. Open spaces similar to the one between the legs of the model in the illustration are also filled with clay to form the *area of separation*, as seen in Figure 14 *c*. After the cracks between the model and the board are filled with clay, the boards may be given a coat of shellac if desired; however, this is not essential. Plaster is mixed and applied over the boards next to the clay strip around the piece of sculpture, as seen in Figure 15 *a*. The plaster should not come in contact with the figure.

Before the plaster has fully set, a steel straight edge, a broad putty

* For further information about separating mediums see *Molding and Casting* by Clarke, Standard Arts Press, Baltimore, Md., 1946.

A

B

Figure 15. *a,* Plaster is applied over the wood wall in order to get a smooth edge. *b,* This is smoothed with a flat edge scraper as the plaster sets.

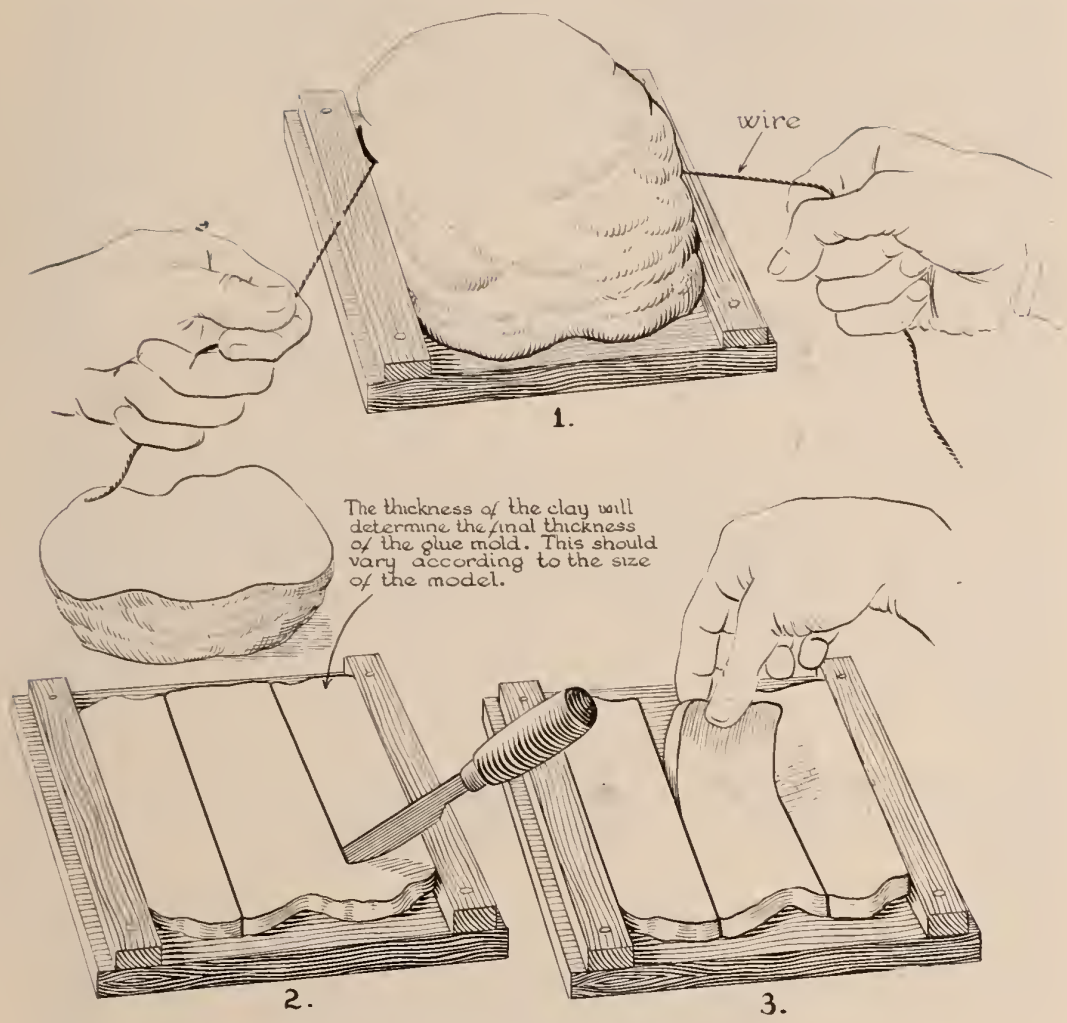
wire
1.
The thickness of the clay will determine the final thickness of the glue mold. This should vary according to the size of the model.
2.
3.

Figure 16. A simple method of cutting flat pieces of clay.

knife or a similar scraping device is used to make the plaster flat or ribbonlike, as seen in Figure 15 *b*. This forms a separation wall for one side of the agar mold and the mother mold. When the top surface of this plaster wall has been smoothed off, the rough outer edges are cut away. The rough edge of the clay next to the model is cut smooth, but no effort should be made to fill in the cracks and crevices in the clay adjacent to the model. The ribbonlike plaster wall is given a coat of shellac or lacquer, then oiled to prevent the shell or mother mold (which will be made later) from sticking.

Next, a large ball of clay is placed between two wooden rails, as seen in Figure 16. A wire is used to cut the ball of clay into flat pieces of the same thickness. These flat pieces of clay are placed over the model,

Figure 18. *a*, Cylinders of clay are put in place for providing pouring holes and air vents in the plaster. *b*, The plaster mother mold is applied.

Figure 19. *a*, Reinforcing fibers are added to the plaster. *b*, After scraping the excess is brushed away.

the plaster-water mixture is applied. As a rule, wood or excelsior, hemp fiber, pieces of burlap or a similar fibrous material is dipped into the plaster-water mixture to give it additional support on setting. Excelsior is being used for this purpose as seen in Figure 19 *a*. More plaster is applied after the shell has been supported in strategic places with a fibrous material. The shell is then made smooth. Tiny particles of plaster may be brushed away after setting, as seen in Figure 19 *b*.

The lifting irons are grasped and the hands inserted under the board wall, where they hold the model in place in the clay while the half shell and the model are turned over, as shown in Figure 20 *a*. The exposed clay surfaces are smoothed and the cracks next to the model are filled in with additional clay until they are smooth and at sharp right angles to the model.

A coat of shellac is applied to the clay to prevent the agar composition which is to be poured later from absorbing water from the clay, thereby making the agar too soft at the junction of the two pieces.

Registration grooves or notches are then cut or bored into the shell or mother mold, as seen in Figure 20 *b*. These cause the two halves to register or fiit together closely in their proper place. It is unnecessary to cut the registration grooves in the clay because the shells will hold the pieces of the agar mold in place. When the shellac on the clay is dry, the clay and the edges of the shell are given a coat of mineral oil. This aids in the separation of the second section of clay and shell which is to be made adjacent to the clay section and completed half shell.

Flat pieces of clay are laid over the back of the model, as seen in Figure 21 *a*, to form the space for pouring the second half of the agar mold. These are smoothed out and a triangular strip of clay is added to the edge to form a separation groove. Cylindrical pieces of clay are added to form pouring holes and vents in the plaster shell. They may be seen in Figure 21 *b*.

An application of mineral oil is made to the water-clay surface to aid in separating the clay from the plaster, which will be applied later.

The first coat of plaster is then applied to the surface of the clay and should cover the entire surface to a thickness of about one-quarter of an inch. After this the supporting and lifting irons are put in place. Wet excelsior is dipped into plaster and forced around the irons. The plaster shell is then built to the proper thickness and smoothed.

The model and shell are turned to rest on the top end, with the base up, as seen in Figure 23 *b*. Registration grooves or notches are bored in the base of each shell. A cap of plaster is made over the end, as shown in Figures 24 *a* and *b* and 22. After setting, the cap is removed as

Figure 20. *a*, The mother mold is turned over. *b*, The clay around the pattern is made smooth and registration notches are bored into the plaster mother mold.

Figure 21. *a,* Clay strips are placed on the opposite side of the pattern. *b,* The clay is rubbed smooth and a triangular registration ribbon of clay is applied. The pouring holes and air vents are indicated.

Figure 22. *a*, The second half of the mother mold is begun. *b*, This is reinforced with a fibrous material and the handling irons are applied.

Figure 23. *a,* The completed two halves of the mother mold. *b,* The mold is placed on end in preparation for making the cap on the bottom. A separating medium is applied.

seen in Figure 25 *a*. One half of the case is opened and the clay removed. The clay is trimmed smooth at the pouring vents to provide openings for the agar composition. Defects within the mother mold are filled with clay. The surface is cleaned of plaster particles by means of a bellows as seen in Figure 26 *a*. The model is wiped clean of any moisture that may have collected from the clay. The clay edge is then shellacked to prevent it from absorbing the glycerin or sorbitol from the agar composition. Talc, or powdered soapstone, is dusted on the model to further absorb moisture and to help as a separating medium.

The plaster shell is replaced over the model, which is still encased in half of the clay, and clamps are hammered into the shell to hold it together. The surfaces around the pouring holes are shellacked, funnels for pouring the agar are put in place, and the edges covered with clay to prevent leakage when there in an overflow. During the pouring the agar rises in the vents at lower levels before it comes to the surfaces at higher levels. While the vent pipes can be removed and the openings stopped up with clay, it is better to wait until the agar sets before this is done. Figure 27 *a* shows the funnel and vent pipes in place. In Figure 27 *b* the agar composition is being poured. After the agar has set, the entire mold is turned over and the other half of the case over the clay is removed and the clay is taken from that half of the case. This leaves the model encased in only half of the agar mold. The inside surface of the shell over the clay is cleaned and scraped smooth. Any imperfections in the form of depressions on the inside surface are filled with clay. The surface is brushed off carefully and given two coats of shellac, or shellacked until it shines or no longer absorbs the separating medium. If the shell is to receive a glue composition rather than agar, it is given a good coat of petroleum jelly, because glue sticks to the shell more readily than agar does.

The edges of the shell containing the agar and the model are cleaned so that they fit perfectly. Otherwise there will be fine paperlike or feather edges of agar hanging from the agar mold between the two pieces of the mother mold when the model is removed. Two coats of shellac are applied to the edge of the agar mold, as seen in Figure 29 *a*. The model is cleaned and oiled, then soapstone talc is applied sparingly to dry up the oil and help in separating. Figure 28 *b* shows the model encased in the set half of the agar mold. The worker in the illustration is wiping the clay and moisture particles from the model after the clay was removed. If the model has been well oiled, there is little possibility of the clay sticking to it. However, moisture collects quite rapidly on the model from the wet clay. The heat generated by the setting plaster shell vaporizes the water in the clay and causes these sweatlike particles of moisture to form on the cold model. The model should be well cleaned and re-oiled.

Figure 24. *a*, The plaster cap is started. *b*, The edges of the plaster cap are scraped smooth, exposing the join line.

Figure 25. *a*, The cap is removed. *b*, After opening the mother mold, the clay in one half of the mother mold is removed.

Figure 26. *a*, Half of the mother mold is cleaned by the use of a bellows. *b*, Half of the mother mold and the cap are replaced and clamped together

Figure 27. *a*, The pouring funnels and vent pipes are put in place. *b*, The molding composition is poured.

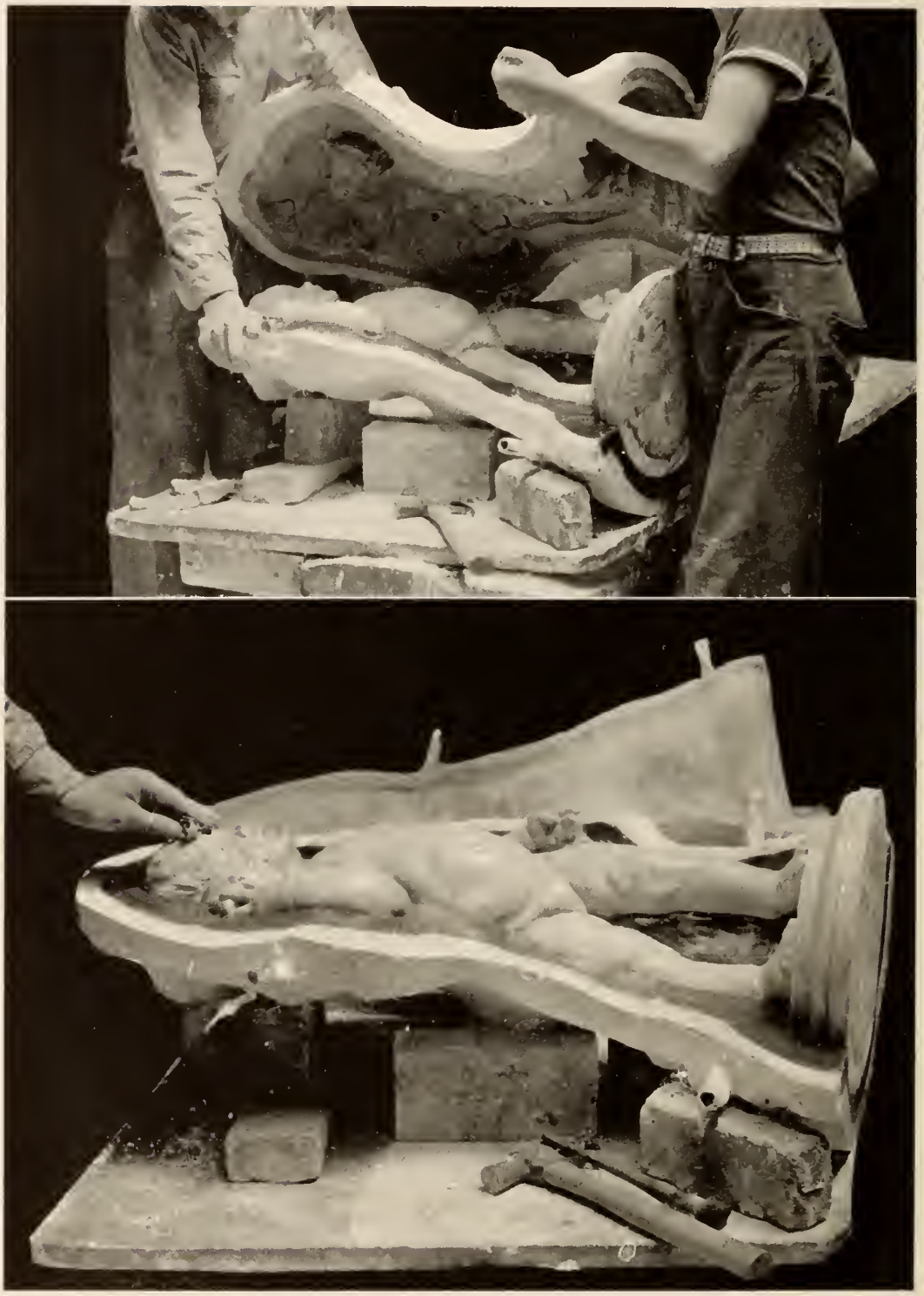

Figure 28. *a*, After the molding composition has set, the mold is turned over and the mother mold covering the reverse side is removed. The clay is now removed from this side. *b*, The model is cleaned and a separating medium is applied in preparation for pouring the second half of the mold.

The shell is then replaced over the model, as seen in Figure 29 *b*, and clamps are hammered into place to hold the two halves of the shell together. The base of the shell is also replaced.

The agar or glue composition is heated until completely melted and then allowed to cool to a point where it will not remelt the edge of the opposite side of the agar or glue mold which has set. This can be tested by cautiously placing a finger in the mixture. If the heat is bearable or the finger can be held in the composition without discomfort, it is ready to pour. This is very important in glue molding, as the set glue edge will remelt readily when the hot glue composition is poured against it, thus uniting the two halves of the glue mold. The agar edge in agar molding will stand more heat. However, it is always advisable to do each step of the process exactly according to the laws that have proved to be successful. This caution is a safeguard against ruining a step in the process, which in turn may prevent the necessity of doing over the entire work. The funnel and risers are placed on the case and their bases surrounded with clay to prevent leakage. When the temperature of the composition has reached the point where it is comfortable to the finger, the composition is poured and allowed to stand until set.

The agar in the average mold sets in a few hours, seldom more than two or three hours. If glue is substituted for agar, it is best to allow the glue to remain in the mold over night in a cool place before removing the case. While the agar or glue is being poured, the risers or air vents should be watched to see when the composition rises. The very small vents may be covered with clay to prevent overflowing as the workers are doing in Figure 30 *b*. If a vent is small, it is not necessary to put a pipe over it. The funnel which is placed at the highest point of the mold is used for the pouring. The vents serve only as risers or spaces in which the liquid agar composition can rise without forming air pockets. These vents can be made from sections of brass pipe, or pieces of tin rolled in a cylinder and soldered together. The agar is allowed to rise in them. These risers or vent pipes also feed back material to take up the cooling shrinkage.

After complete setting the pouring funnel and vents are removed. The mold is pried open and the model removed, as seen in Figures 31, 32, and 33. The agar composition that rose into the pouring vents is easily cut away, as illustrated in Figure 31 *b*. The shellac is wiped off the edges of the agar mold and any remaining particles of waste plaster are removed from the inside surface. Before painting the inside surfaces of the agar mold with the wax which is to form the cast, a small section may be cut from the agar mold to allow the wax-resin mixture (which will be poured later) to flow from one locked part

Figure 29. *a*, A close-up of the separating medium being applied. *b*, The second half of the mother mold is put in place.

Figure 30. *a*, The bottom of the mother mold, showing the filled and unfilled sides. *b*, The cap is replaced and the molding composition is poured to fill the second half of the mold.

Figure 31. *a*, After setting, the mother mold is removed from half of the mold. *b*, The areas that have risen in the funnels and vent pipes are cut away.

Figure 32. *a*, Half of the mold is removed from the model and replaced into the mother mold. *b*, The mother mold is then removed from the remaining mold.

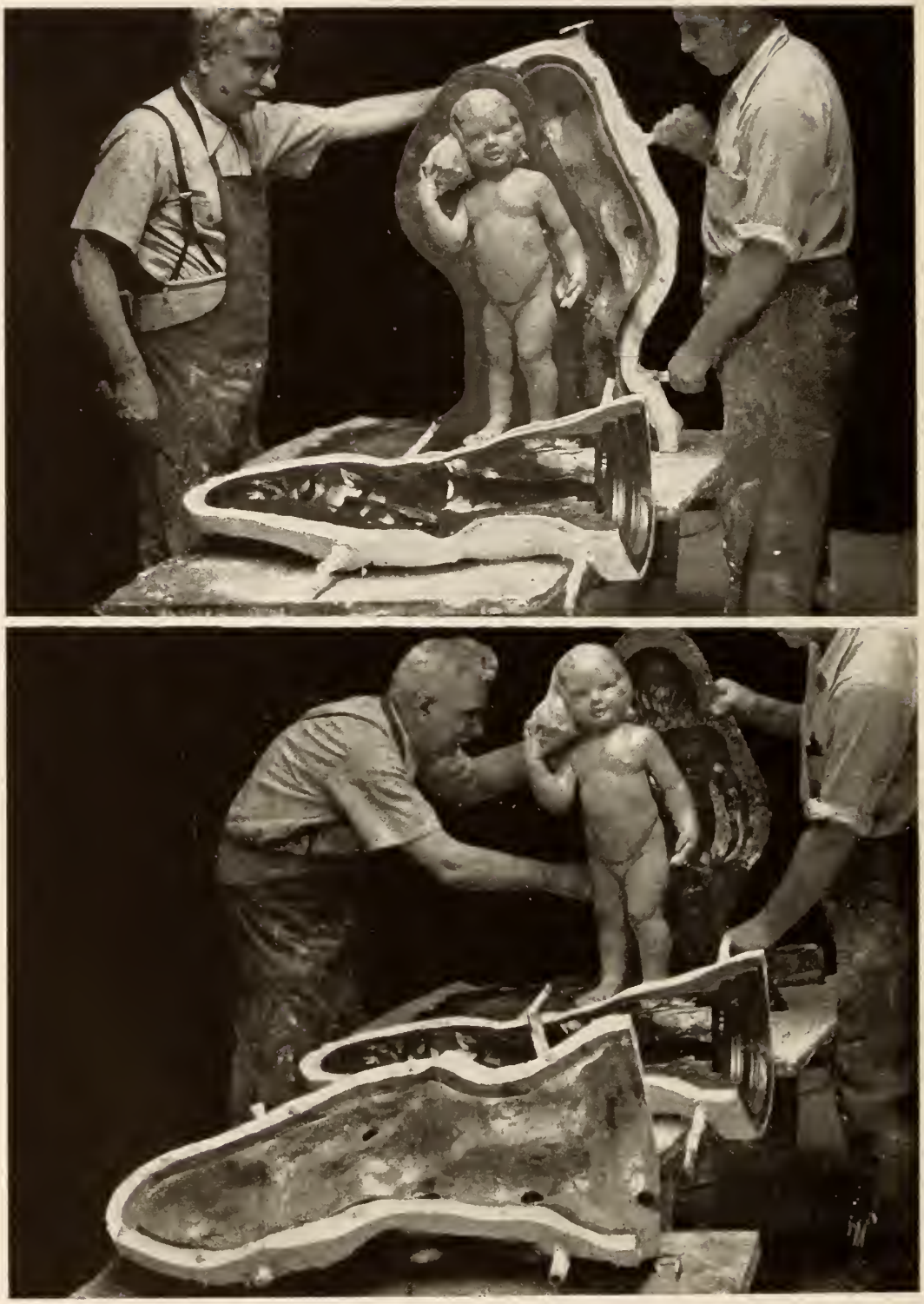

Figure 33. *a*, Half of the mold still remains on the model. *b*, This half is removed and placed in the mother mold.

of the agar mold to another. For example, this is done between the hand and leg. The hand is adjacent to the leg but not connected to it. A small block is cut out of the agar mold at the end of the impression of the finger to the leg. This allows the wax to flow through the opening created by the removal of this block, otherwise an air pocket may form at this point and produce a faulty cast of the hands and fingers. After the two halves of the mold and case are put together and poured with wax and the set wax impression removed, this block is cut away on the wax cast or it may finally be cut away when the cast is in metal. Wax gates and vents may also be added later at this point to facilitate the flow of metal.

CHAPTER X

WAX-RESIN COMPOUNDS

For the first coat of wax-resin composition that is applied with a brush directly to the agar mold, Mario Scoma[1] recommends the following mixture:

	Parts by weight
Beeswax	2 to 3
Rosin (colophony)	1

English vermilion—sufficient amount to color.

I prefer to add about ten per cent of carnauba wax to the above formula to facilitate the casting of sharp detail. Furthermore, it makes the correction of defects more easy to obtain when they have to be carved into the wax cast. However, the carnauba wax will slightly raise the setting point of the wax-resin mixture. This is an advantage in hot weather. In winter this slight raise in melting point may be offset by the addition of about ten percent of petroleum jelly if it is desired to lower the melting point. A small amount of kerosene oil may also be added in winter to keep the mixture from setting too rapidly.

Malvina Hoffman[2] published the following formulas for use in making the wax cast:

"Average Ingredients of Wax for Bronze Castings

1

Pure yellow beeswax	1 lb.
Turpentine of Venice	4 oz.

2

Pure yellow beeswax	1.3
Pure bleached wax (white)	0.1 2 kg.
Paraffin	0.4
(Colophane) resin	0.2

3

Pure yellow beeswax	10 grams
(Colophane) resin	10 grams
Carbonate of lime	90 grams
Olive oil	90 grams

"Each one of these compounds can be colored either with green or red sterate or with English vermilion. Add until the wax is colored to the shade desired.

"Melt the wax and then add coloring matter. Stir well.

"In order to melt the wax and prevent it from burning or taking fire, put the pot containing the wax on a very low fire. Some people melt the wax in a double boiler. This is a good idea. In case a double boiler cannot be secured, a sheet of asbestos is put between the flame and the pot. *Great care* must be taken not to allow a drop of turpentine to splash into the flame.

[1] Scoma Foundries, Brooklyn, N. Y.

[2] Hoffman, Malvina: *Sculpture: Inside and Out*, P. 305., W. W. Norton & Company, New York, 1939.

"In my own experience I have found that compound No. 1 is the best, and the formulas given is in general correct, but sometimes according to the quality of the wax the proportion of the turpentine of Venice has to be changed. After the wax has been melted, wait until it cools and then see if the consistency is good. If not, add a little more turpentine of Venice and melt again. In order to determine when the wax is ready for use, allow a little of it to cool, and rub it between your fingers and thumb. It should have a very fine plastic quality."

Hoffman does not write whether these mixtures are to be painted or poured into the mold, or whether the same mixture is to be used for painting and pouring. However, it is assumed that it is to be used for painting only.

Unfortunately, the craftsmen using these waxes and resins have developed their own technic for using them. They work, as a rule, according to "feel" rather than according to scientific data such as that gained from the accurate use of weights and measures. They "feel" that their mixtures are right. This knowledge is gained from considerable experience and, of course, it is better to have the actual experience rather than the compilation of scientific data and no experience. The beginner can only use published material or apprentice himself to a master until the knowledge is acquired. If one has gained experience from considerable work with waxes and resins he can find numerous flaws in the published material.

In Hoffman's formula No. 1 both beeswax and Venice turpentine are used. These are quite expensive when compared to common resin (colophony) and one of the microcrystalline petroleum waxes such as "Petro Wax", or even paraffin of a melting point similar to that of beeswax, 62-65 C, (144-147 F). An excellent substitute for Venice turpentine can be made at a fraction of its cost by combining common resin and spirits of turpentine.

Both bleached and natural beeswax are used in Hoffman's formula No. 2. The slight difference in color that can be obtained by the use of bleached beeswax hardly warrants its use. All other factors, such as melting point, solubility, specific gravity, are the same in bleached and natural beeswax. Most resins darken considerably when heated, unless the temperature is kept rather low. This darkening is accelerated if the mixture is melted in either a copper or an aluminum pot. An enameled, crockery or polished steel pot is satisfactory. Consequently, the lightness of color gained by the use of bleached wax would be lost on heating. There are many grades of rosin, distinguished mostly by color. All can be used regardless of color, so long as they are clean and the worker knows how to vary the melting point of his mixture by the addition of waxes or petroleum jelly. Colophony or common American rosin can be substituted for practically any of the other resins that are employed in this work.

This would also apply to formula No. 3. Today, the cost of the olive oil listed as ingredient in this formula is practically prohibitive.

A nondrying vegetable oil such as corn oil or cottonseed oil or mineral oil could be used instead.

In none of these formulas is the use of carnauba wax considered. This wax has two very definite advantages. First, it changes the flowing qualities of most resin-wax mixtures. Even when the content is kept low as, for example, one part of carnauba wax to twenty parts of the remaining ingredients, the resulting wax cast is sharper in detail. In other words, if a formula contains a small percentage of carnauba wax an impression of the pores of the skin or the pattern of a fingerprint may be obtained in sharp detail. If the carnauba wax is omitted, these details are soft and lack sharpness.

The other great advantage in the use of carnauba wax is that it raises the melting point of the wax-resin mixtures and makes them more suitable for use in hot weather. If it is assumed that carnauba wax is essential to a wax-resin mixture, the mixture can be balanced to suit any weather of normal temperatures. In hot weather additional carnauba wax can be added to the mixture to raise its melting point. In cold weather, mineral oil or petroleum jelly can be added to lower the melting point. It is necessary to keep the melting point low enough to allow the wax-resin mixture to flow into the tiniest details. At the same time it should not set so hard as to crack or lift from the surface of the mold or cause border lines where a new application of melted wax is painted over or applied adjacent to cold or set wax. (For further detail on this subject see *Molding and Casting 3.*)

In most cases the wax-resin mixture used for painting on the surface of the mold is of a lower melting point than that used for pouring into a closed mold. The pouring mixture is used to produce the desired uniform thickness that will finally be replaced by metal.

At this point it is of importance to discuss the properties of waxes and resins in general and their relation to the *cire perdue* process. Much of this information has been gleaned from the writings of Randolph Wardell Johnson[1] and the Chemical Buyer's Guide Book.[2] Considerable additional material on the same subject may be found in Molding and Casting.[3]

Beeswax is used extensively in preparing a colored wax mixture for the first coat to be applied to the mold. It is also incorporated in a modeling wax mixture for direct casting; it is stable and tough, though somewhat too tough and sticky by itself to carve well and too "short" to model well. Often ceresin wax and microcrystalline waxes are substituted. Beeswax from different apiaries varies greatly in ductility and hardness. Melting points: 62-65 C, (144-147 F).

[1] Johnson, Randolph Wardell: *The Practice of Direct Casting.* Technical Studies, Vol. VIII, No. 4, April, 1940; *ibid,* Vol. IX, No. 4, April, 1941.

[2] Chemical Buyer's Guide Book, Chemical Markets, Inc., 25 Spruce Street, New York, 1936.

[3] Clarke, Carl Dame: *Molding and Casting.* Standard Arts Press, Butler, Md., 1946.

Carnauba wax is a hard, brittle vegetable wax having a comparatively high melting point. It has the property of raising the melting point of most wax-resin mixtures, but causes slight shrinkage in proportion to the amount added. It improves the flowing qualities of wax mixtures and makes it possible to obtain details that most waxes fail to record. Even when the carnauba content is kept as low as one-twentieth of the mixture this quality of obtaining detail still persists. Melting points: 84-86 C. (183-189 F).

Ceresin wax is similar to paraffin in many respects, with some of the qualities of beeswax. It is cheaper than beeswax and in many cases better, because it is tough and does not sag as readily. Furthermore, when incorporated into the mixture to the extent of 30 per cent it produces a more homogeneous composition that sets smoothly and without granules. For these reasons ceresin wax is generally used in pouring mixtures. The microcrystalline waxes, Petro wax and Micropar B may be substituted at a substantial saving. Melting points: 61-78 C, (142-172 F).

Halowax, a synthetic noninflammable wax that has a very high melting point. It is hard, strong and tough and gives a milky opacity to wax mixtures in the chilled state.

Lanolin (adeps lanae) imparts plasticity to wax mixtures for use in cold weather. Its high cost often makes a substitute necessary such as petroleum jelly.

Lead oleates: According to Johnson, lead oleate greatly improves the ductility and plasticity of a wax-resin mixture for modeling in direct casting. It is poisonous material and must be kept out of the mouth and otherwise handled with care. Since it is sometimes difficult to obtain, it can be made from the following formula:

	Parts by weight
Olive oil	1
Lard	1
Lead monoxide	1
Hot water and borax—sufficient quantity	

The oil and lard are heated until mixed together. A half ounce of borax is mixed with each quart of hot water used. The water is added to the lead monoxide until a stiff paste is formed. The oil-lard mixture and the lead monoxide are mixed while stirring briskly over gentle heat until complete emulsification takes place. This produces a buff-colored paste that gradually stiffens with age to a brittle solid.

Micropar B* is one of a series of petroleum microcrystalline wax mixtures similar to Petrowax. It also has many of the properties of beeswax and ceresin wax and serves as an excellent substitute because it is less expensive and its properties are more constant. Melting points over a rather wide range are obtainable.

* Gulf Oil Corporation of Pittsburgh.

Paraffin wax is used to dilute other mixtures, improve the carving qualities, and to lesson stickiness. It may be purchased in lots having varying degrees of melting points, such as 48 C to 62 C, with many specific melting points between these two figures. This wax is semi-transparent, odorless and brittle, especially paraffin with higher melting points. Melting points: 48-62 C, (118-144 F).

Petroleum jelly (petrolatum) is one of the best and cheapest materials for lowering the melting point of a wax-resin mixture to make it suitable for modeling. However it tends to impart shortness to modeling compositions. Melting points: 45-48 C, (113-118 F).

Petrowax is one of the microcrystalline petroleum waxes. It is quite plastic, even more so than beeswax, though darker in color. It is decidedly plastic in character when compared with amorphous waxes of similar high melting points. For example, at 40 F it has a durometer hardness of 54, whereas other waxes with similar melting points show a durometer hardness of 75 to 85. Melting point: 55.5 C, (131.9 F).

Pitch, burgundy: There are various types of pitch, such as pine, palm, cike, coal, tar, wool, and vegetable pitch. Johnson claims this material to be superior to resin because it is tougher and less brittle.

Resin (colophony) as well as other well-known resins increases the plasticity and ductility and gives stickiness to wax mixtures. It causes the composition to hold its plasticity over a longer period of time. When a modeling wax-resin mixture is high in resin content the hands are oiled to prevent sticking and facilitate handling. Resin causes the mixture to set hard and brittle. When the resin content of wax-resin mixtures is less than three-fourths of the entire compositions, insoluable resins are precipitated to the bottom and side of the melting pot. This is particularly true if mineral waxes, which are often used, are incorporated in the mixture. If the composition is melted in a copper or aluminum pot these precipitations take place more readily. Furthermore, the resin darkens quite rapidly. Better results are obtained if the composition is melted in an enameled, crockery, or polished steel pot. Of course a double boiler should be used if crockery is employed. This precipitation of the resin to the sides and bottom of the pot may be reincorporated into the mixture by the addition of more resin until the precipitation ceases. Colophony softens at 70-80 C, (160-176 F), and becomes a semifluid in boiling water. The temperature should not be higher than 135 C, (275 F).

Turpentine, Venice can be used in place of resin or pitch in modeling waxes where a smaller quantity is required to produce ductility and plasticity, and produces a mixture that is less brittle. The same result can be accomplished by adding spirits of turpentine to resin. Venice turpentine is decidedly more expensive than the resin-turpentine mixture. There are two types, true and artificial Venice turpentine. They are sluggish flowing liquids.

Tallow may be used to lower the melting point of wax mixtures. It is of animal or vegetable origin and some tallows become rancid in time. animal or vegetable origin, and some tallows become rancid in time. Vegetable tallow solidifies at 27-35 C, (81-95 F).

Johnson gives the following formulas that he uses for the purpose of modeling onto the core and for dipping a modeled core in the melted wax, as is customary in direct casting.

FORMULA W1

	Parts by weight
Beeswax	16
Lead oleate	1

(A hard, stiff wax suitable for very small work.)

FORMULA W2

Beeswax	16
Paraffin	16
Lanolin	1
Lead oleate	1
Venice turpentine	1

(Softer and more ductile than W1.)

FORMULA W3

Beeswax	24
Tallow	7
Ceresin	16
Carnauba	8
Paraffin	8
Lead oleate	5

(This mixture was colored with a little Prussian blue oil color thinned out with very old and sticky castor oil. Its slight shortness makes it easy to scrape.)

FORMULA W4

Beeswax	1
Paraffin	1
Ester rosin[1]	1

(A cheap simple mixture that works well in warm weather.)

FORMULA H2

Beeswax	24
Ceresin	21
Paraffin	16
Carnauba	16
Halowax	24
Lead oleate	9
Burgundy pitch	9

(A creamy, opaque mixture that rolls between the fingers when warm.)

[1]"Rosin is esterfied by the addition of 10 per cent glycerin. This hardens and toughens it. My first experiments with ester rosin seemed to indicate that it causes less precipitation than plain rosin."

The following are "dipping" rather than "working" waxes, being designed for cutting and scraping cleaning. They are brittle rather than ductile or plastic.

FORMULA H1

	Parts by weight
Beeswax	8
Paraffin	16
Ceresin	21
Carnauba	16
Halowax	8

(A hard, opaque, white wax, with strong shrinkage.)

FORMULA W5

Beeswax	1
Paraffin	1
Ceresin	1

(A transparent, yellow, foundation wax. If, in dipping, the successive layers of this wax tend to separate, add a little resin or Venice turpentine.)

FORMULA H3 ("Ivorite")

Halowax	16
Carnauba	1

(Opaque, white, and very hard, with high melting point. If there is insufficient adhesion between layers of this material, when dripped, add about ½ part of copal or dammar. I developed this material about four or five years ago, at which time I exhibited a few small reliefs in it under the name of "Ivorite". It is a hard, opaque, white material resembling ivory. It carves beautifully, can be smoothed with steel wool, and polished with a cloth wet with turpentine. It is heavier than water and melts well above the boiling point of water. Hence, if one uses it for dipping, one must melt enough material completely to cover the core or armature in the tank, the water-floating method being inapplicable. It is noninflammable and models, in northern climates at least, can be left in the sun with little danger of melting down.)"

I have found that the microcrystalline petroleum waxes Petrowax and Micropar B, are excellent substitutes for the waxes commonly used in the lost wax process, such as ceresin, at considerable savings. In other words, a knowledge of waxes and resins in general serves advantageously in the *cire perdue* as well as other processes employing such materials. The following essential factors may be repeated.

1. To raise the melting point of a wax-resin mixture waxes having high melting points should be used, or carnauba and similar waxes of high melting point should be added.

2. These waxes should not exceed one-fourth of the content of the mixture, otherwise oxidized resin will separate from the mixture and form a gum in the bottom and sides of the wax pot. The wax will

be less suitable for modeling in the hands, for making strips to cover thin places in the mold, and for rolling into gates, columns and risers. Of course, wax for painting the first coat on the mold can be lower in resin content than a mixture suitable for pouring.

A formula suitable for painting into the mold is as follows:

	Parts by weight
Micropar B	10
Petroleum jelly	2
Rosin (colophony)	32
Carnauba wax	1
Oil-soluble dry color or dye	q.s. (sufficient quantity)

The melting point of this mixture may be lowered by the addition of more petroleum jelly. It may be raised by the addition of more carnauba wax.

The following is a simple formula for pouring to build up an even thickness after the mold has been painted with the above formula:

	Parts by weight
Petrowax	1
Rosin (colophony)	3

The melting point of this mixture can be raised or lowered in the same manner previously mentioned.

In both formulas one of the other microcrystalline waxes or even paraffin can be substituted for the Petrowax. In the first formula it is advisable to choose one that is light in color. Carnauba wax is omitted from the second formula since no effort is made to record detail. However, carnauba wax can be added to this mixture in summer for making gates, risers and columns.

Mario Scoma uses the following formula for painting into the mold:

	Parts by weight
Beeswax	2 to 3
Rosin	1
English vermilion or lampblack	q.s.

In the winter months a small amount of kerosene is added. Turpentine would also prove satisfactory.

The formula used by Scoma for pouring over the painted wax mixture is as follows:

	Parts by weight
Ceresin wax	1
Rosin	3

The same mixture is used for making columns, vents and gates, also for placing as thin strips over the raised lines or areas of the mold. Otherwise these would be thin when the mixture is poured because wax has a tendency to flow away from raised lines and leave them thinner than surrounding areas. These strips of rolled mixture are put in place immediately after the mold is painted with the first coat.

CHAPTER XI

INVESTMENT COMPOUNDS

There are many materials suitable for making the core and mold for use in metal casting. The formula previously mentioned of one part plaster, one and a half silica and one and a half luto is simple and serves well for both the core and the mold; however, other substances also are suitable for this purpose. The following materials are used for making cores and molds into which molten metal may be poured. The amount of each ingredient in a formula may vary according to the subject, its size, and the availability of the material. Specific formulas will be given later.

1. *Asbestos.* The short fibered or floated asbestos lightens the mold and gives tensile strength and porosity. Asbestos also lowers the coefficient of thermal conductivity. Therefore, a mold containing asbestos allows the metal to flow further without chilling so readily. Asbestos can be used, up to one-half the total volume of the mold. If more is used, cracking is likely to result. In other words, too much asbestos makes the mold crumble.

2. *Ashes.* Ashes give porosity and prevent cracking of plaster molds. Coarse ashes can be used in place of luto or grog. Any charcoal in the ash serves as organic matter. (See grog, luto, and organic matter.)

3. *Clay.* Fire clay, New Jersey ball clay, and similar clays are used to bind together other materials and to give plasticity to the resulting mixture. The composition obtained from the use of large percentages of clay bakes hard, and often makes it difficult to remove the mold, and especially the core, from the metal cast. Too much clay in the mixture for the first applications may cause fine surface cracking of the mold. This can be prevented to some extent by the addition of more organic matter to make the clay less short. Too much clay also causes shrinkage. The amount of clay used should not exceed one-sixth of the total volume. Clay in the mixture reduces the strength of the wet mold but increases the strength of the fired mold.

4. *Grog.* Grog is crushed burnt clay, and rough grog generally is made from old china, pottery and stoneware. Usually the finer grog is brick dust obtained from brick kilns. Both the coarse and fine grog serve a definite purpose. The fine brick dust can be used in place of silica or silex and mixed with plaster to form the mold. The coarse grog may be used as luto to reduce the shrinkage and cost of the mold, since it acts as a filler. The grog absorbs the water from the molding mixture before the plaster sets, thereby increasing the strength of the mold. It must be applied quickly to the surfaces to obtain detail before setting, or the mixture must be quite fluid before being applied. A small

amount of retarding agent added to compositions containing plaster of Paris retards the setting time. Liquid glue is often used for this purpose but is not desirable. A better material, obtainable at any building materials supply yard, is commercial retarder, which has a uniformity not found in glue; one ounce per 100 lbs. of plaster slows it down twenty to thirty minutes. The maximum quantity of grog used should not exceed two thirds of the total mixture.

5. *Luto.* Luto is obtained by crushing baked plaster-silica molds into a coarse powder. However, the term would probably refer to any crushed mold that has been previoulsy baked and used. Luto is employed as a filler in making additional molds. It decidedly reduces the shrinkage and cost of the mold and increases its strength, because luto absorbs water from the other ingredients. Luto alone is not suitable for mold making and can serve only as about one-third of the total ingredients. In any event, where luto is employed, one-fourth to one-third of the mold mixture should be new plaster. Luto has a variable effect on the setting time of fresh plaster, and must be used with care.

6. *Organic matter.* This may consist of a number of varieties, such as charcoal dust, chopped straw and other vegetable fiber, hair clippings, cloth shearings, loam, moss and similar organic substances. These materials decay when kept damp and cause the molding composition to become more plastic when applied to the wax cast. When the mold is baked, the organic matter is consumed and produces porosity to allow the gases created by the molten metal to escape. Vegetable or animal fibers in the organic matter strengthen the mold while it dries. Later these are consumed in the baking. The mold then becomes more porous for the escape of gases.

Randolph Wardell Johnson prepares an organic mixture in the following manner. He places cotton rags, jute sacks, chopped straw, cotton mattress stuffing, hair clippings and similar materials in a large crock. To these he adds a small quantity of clay and sand. They are kept damp for several months or years, the digesting or decaying process being stimulated from time to time by the addition of such fermenting agents as old cider and whey. When the composition has rotted considerably, he stirs into it the following mixture and gives directions for its use.

"Dry New Jersey ball clay, crushed, two parts by weight. (Fire clay or local blue clays may be used instead, but will be less plastic and take less sand.)

"Luto, one part by weight (formula P1.) If no luto is available, use silex or ashes (through 60-mesh). Ground charcoal in place of part of the luto (or ashes) will improve the mixture.

"These are shaken into hot water and stirred thoroughly to make a thick cream, which is rubbed through a $\frac{1}{8}$ inch sieve.

After the plaster has been removed from the pattern, the two halves of the mold should be laid on a steel or other rigid frame, preferably face up, or on edge, and put in a drying oven which can be maintained at from 93.3 C to 148.8 C (200 to 300 F), until the mold is apparently dry. This operation removes the free water from the mold. After the mold is apparently dry, the heat may be raised to 260 C (500 F), or higher to remove the combined water from the plaster. For small molds an ordinary gas heated oven may be used; for larger ones a refractory lined furnace is satisfactory. The removal of combined water should be done under heat prolonged for a sufficient time to bring the mold to a constant weight. If the mold is desired in a hurry, the drying temperature for the combined water can be increased safely up to 537.6 C to 815.5 C (1000 to 1500 F.), without affecting the mold. It is absolutely necessary, however, that both the free and the combined water be removed thoroughly from the mold, since metal will not lay tight against the mold faces when any moisture is present.

The hot mold should not be chilled suddenly, for this may cause thermal cracking.

Best casting results are obtained when the mold is used hot, just from the oven, and the metal poured into it relatively cold. The plaster mold is a much poorer conductor of heat than a sand mold and for this reason, if the metal is too hot, large and undesirable crystal development may occur because of the slow heat loss. In pouring, the two halves of the mold are blown clean with compressed air, fitted together, clamped between two plates of steel provided with the necessary opening for the sprue and any required risers. The clamping should be done carefully so as not to crush the mold at any point, and yet it should be tight enough to prevent metal leakage at the joint between the halves of the mold.

Metal casts in a plaster mold remain fluid for a longer period of time than metal casts in a sand mold. For some types of metal this, of course, is unsatisfactory as there is no chilling effect obtained. However, in the majority of cases the casting will be completely normalized since there is no chilling action involved on one surface and no internal strain within the casting created by uneven cooling.

A plaster silica mold can only be used once. It is preferable to allow it to remain undisturbed until the metal has set completely. After this, investment compound may be broken from the casting, but the casting should not be chilled with water until cooling has progressed to the point where water will not cause cracking as a result of thermal strain.

After removal of gates, risers and sprues, the casting may be cleaned by any suitable pickling solution, or by wire brushing, which will develop a bright metal surface. In casting bronzes or other alloys, where

a patina is to be developed and chasing or finishing, if started, must be completed over the entire face of the casting, it is preferable to arrange the gating in such a way that the face will not have to be trimmed. In this way the excess cost of chasing or finishing is avoided and, quite frequently, will save enough on labor to permit the use of plaster molds in ordinary production.

The United State Gypsum Company furnished the following table for making a comparison between metal casting and plaster and sand castings:

	Sand Castings	*Plaster Castings*
Metal content	High	20 to 40% less than sand
Internal strain	High and uneven	"Normalized" (practically annealed)
Accuracy	Requires machining	Cast to .002" on diameters 3" or under
Drilling and Tapping	Requires clamp fixtures	Clamp fixtures unnecessary. Form fixtures eliminate clamp strain
Trimming	a. Parting line fins b. Gates c. Sprue, risers, vents	a. Smooth—no fins b. Gates c. Sprue, risers, vents
Polishing	a. Rough grind b. Grease wheel grind c. Buff wheel	a. Rough wheel unnecessary b. Grease wheel c. Buff wheel
Regularity of Shape	Usually irregular	Regular
Metals used	All alloys, iron or steel	Most sand cast alloys, aluminum and bronze, but not iron or steel
Appearance	Rough	Smooth, finished appearance
Surface of castings	Cast surface chilled and gritty, often spongy and porous	Cast surface annealed, not gritty, less likely to show spongy and porous structure

The following are some formulas which should be studied for their suitability for the problem to be considered. Immediately after the formula is given the name of the individual advancing the use of the formula or the source from which it was obtained. Sometimes both are given.

	Parts by volume
1. Plaster	2
Silica	3
Luto	3

The luto is omitted for the first coat to the wax and the amount of silica may be increased.

—Mario Scoma, Mario Scoma Foundries.

	Parts by volume
2. Kieselguhr	4
Ground charcoal	2
Iron filings (very fine)	1

These materials are ground in a mortar to a fine cream with stale cider. A little clay and molasses may be necessary to strengthen the mixture for large molds.

—Randolph Wardell Johnson, Technical Studies.

3. Windsor Locks sand or French sand is mixed to a smooth cream with whey containing a little clay, molasses and flour.

—Randolph Wardell Johnson, Technical Studies

	Parts by volume
4. Dry asbestos	1
Plaster	1
Potter's flint or silex	1

These are tumbled together, dry, in a barrel. The dry material is shaken into water, mixed to a stiff paste, and applied with a trowel or spatula, not with the fingers. For the facing of molds this formula is good if mixed to a stiff cream and jarred well to remove bubbles. A material that is slightly weaker, but easier to rid of bubbles, is made as follows:

	Parts by volume
Potter's flint or silex (through 80-mesh)	2
FF or dental plaster	1

—Randolph Wardell Johnson, Technical Studies.

	Parts by volume
5. FF plaster	2
Fire clay, finely ground	1
Asbestos floats	1
Crushed fire brick (through 8-mesh)	1
Silex or fine silica sand (through 40-mesh)	1

These can be tumbled together, dry, in a barrel before using.

—Randolph Wardell Johnson, Technical Studies.

	Parts by weight
6. Plaster of Paris	4
Molding sand	4
Fire clay	1

—Dental Formulary.

	Parts by weight
7. Anthracite coal ash	20
Plaster of Paris	30
Powdered soapstone (talc)	3
Mineral red	2

—Dental Formulary.

	Parts by weight
8. Plaster of Paris	7
Asbestos powder	5
Powdered soapstone (talc)	1

—Dental Formulary.

	Parts by weight
9. Powdered soapstone (talc)	1
Plumbago (graphite)	3
Asbestos, grade No. 3	5
Plaster of Paris	7

—Dental Formulary.

	Parts by weight
10. Plaster of Paris	7
Silex	14
Graphite powder	12

—Dental Formulary.

These latter formulas from Dental Formulary are included to give some idea of the various materials used and the proportions that are recommended. In my opinion the plaster content in these formulas is rather high. However, it must not be forgotten that these calculations are by weight rather than by volume. Dental work requires small, fine castings that are most accurate. These formulas should furnish to the research worker a logical beginning from which to develop his own formulas to suit specific requirements. I find that no one formula is suited for every purpose, but that the formula should be changed to suit each particular problem. Furthermore, success or failure seldom depends on a specific formula, but how the formula is employed. Any number of formulas can be used if the operator knows how to use them. Experience, after all, is the best teacher.

W. A. Phair* has described the Capaco plaster mold process for making nonferrous commercial castings from which the statuary caster should gain much valuable information, especially as to the technic of handling plaster molds in great numbers. Essentially, this process is as follows. The molding ingredients contain about 79 per cent of calcined calcium sulfate (a form of commercial gypsum plaster), 20 per cent magnesium silicate (a fibrous strengthening agent), and 1 per cent of an agent to accelerate the setting of the mixture.

The plaster is mixed with other dry ingredients to give it strength, and then purified water is added at the rate of about 180 parts of water to 100 parts of dry material. On a weight basis this would mean a mixture of 6.3 pounds of plaster to 11.6 pounds of water.

The amount of water added is substantially in excess of what would be required to enable the mixture to set. This excess is deliberate, however, for it increases the number of voids left in the material after drying for the escape of gases during the pouring. The pattern impression is established in the mix when it is semiset. The pattern is withdrawn by a vacuum process after the mixture is set, and the mold is baked until completely dry. Baked dry cores are inserted, the cope and drag are joined, and the casting is poured.

The requirements of this plaster mixture are that it contain sufficient permeability to provide a ready egress for all air and gas in the mold during pouring; that it be sufficiently strong to withstand the metal without distortion until the metal sets. It should be sufficiently weak so that it will collapse during the shrinkage of the casting after solidification and thus avoid setting up cooling stresses. By all means the mold should be devoid of moisture when pouring the cast.

* W. A. Phair. *Plaster Molds.* The Iron Age, October 9, 1941.

CHAPTER XII

THE LOST WAX CAST

In preparing to make the wax intermediate stage the mold is painted with the first coating wax-resin mixture. This is continued until the mold is covered entirely. The thickness should be approximately one-sixteenth to an eighth of an inch on a figure three feet high. The wax mixture used for this purpose generally contains a colored pigment such as English vermilion which causes the mixture to be opaque. If translucency is desired, an oil-soluable aniline dye may be used to replace vermilion.

The worker in Figure 34 *b* is applying the wax-resin formula for painting directly to the agar mold. This wax-resin mixture must flow readily into all details before it has time to set, therefore the melting point must be sufficiently low to prevent its immediate setting. A small percentage of carnauba wax added to this mixture improves the flowing quality and makes it possible to record detail that will be sharp and concise. In winter it may be advisable to add a small amount of turpentine, petroleum jelly or naptha to the mixture to prevent brittleness and border lines. If the setting point of the mixture is too high or the temperature of the room too low, border or lap lines will appear where the liquid wax of one brush stroke covers the set wax of another brush the liquid wax of one brush stroke covers the set of another brush stroke.

After the inside of the agar mold has been painted with liquid wax, small strips, ribs, or ribbons of wax are placed over the high ridges as seen in Figure 35 *a*. These wax ribs are generally rolled or pulled out in the fingers and pressed into place as strips over the high edges. The wax mixture used for this purpose is the same as that which is to be poured later. For example, three or more parts of resin to one part of wax will suffice. The object of these ribs is to create an extra thickness of wax at the high edges, which otherwise would run thin when the wax-resin mixture is poured later. The formulas for these mixtures are mentioned in Chapter IX.

When the ribs have been applied to all high edges, the mold is closed and clamps are applied to the edges of the case, as seen in Figure 35 *b*, to hold it and the agar mold together.

The wax-resin mixture for pouring should be heated in advance, as large quantities require considerable time to cool to a point where it can be poured. Before pouring, it should be possible to hold a finger in the mixture without discomfort. After cooling, the mixture is poured into the mold until the mold is completely filled (Figure 35 *b*). Here it remains for a few minutes, depending upon the temperature of the room and the temperature of the resin-wax mixture at the time of

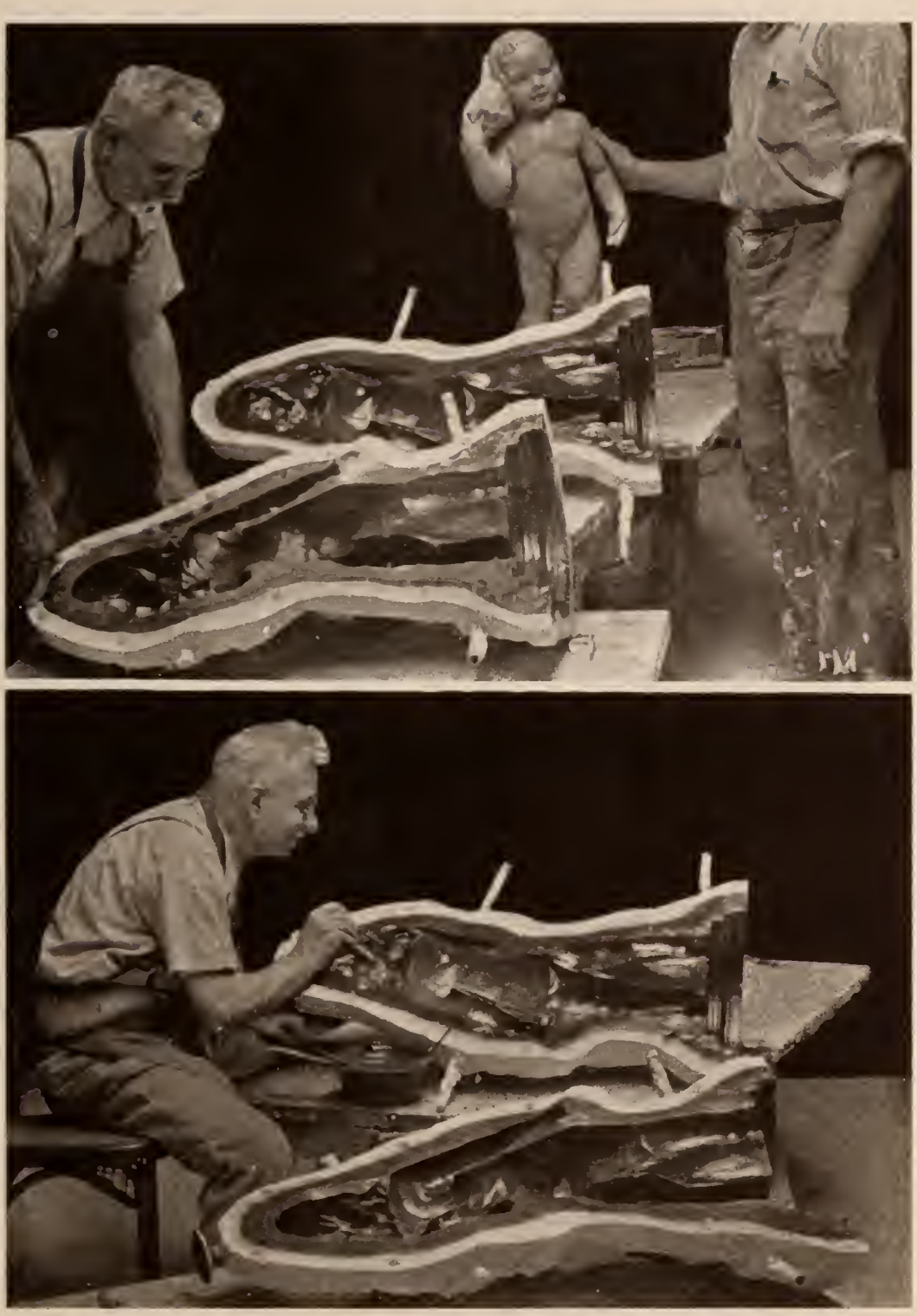

Figure 34. *a*, The pattern, mold, and mother mold after the removal of the pattern. *b*, The painting in of the first coat of wax mixture to record fine detail.

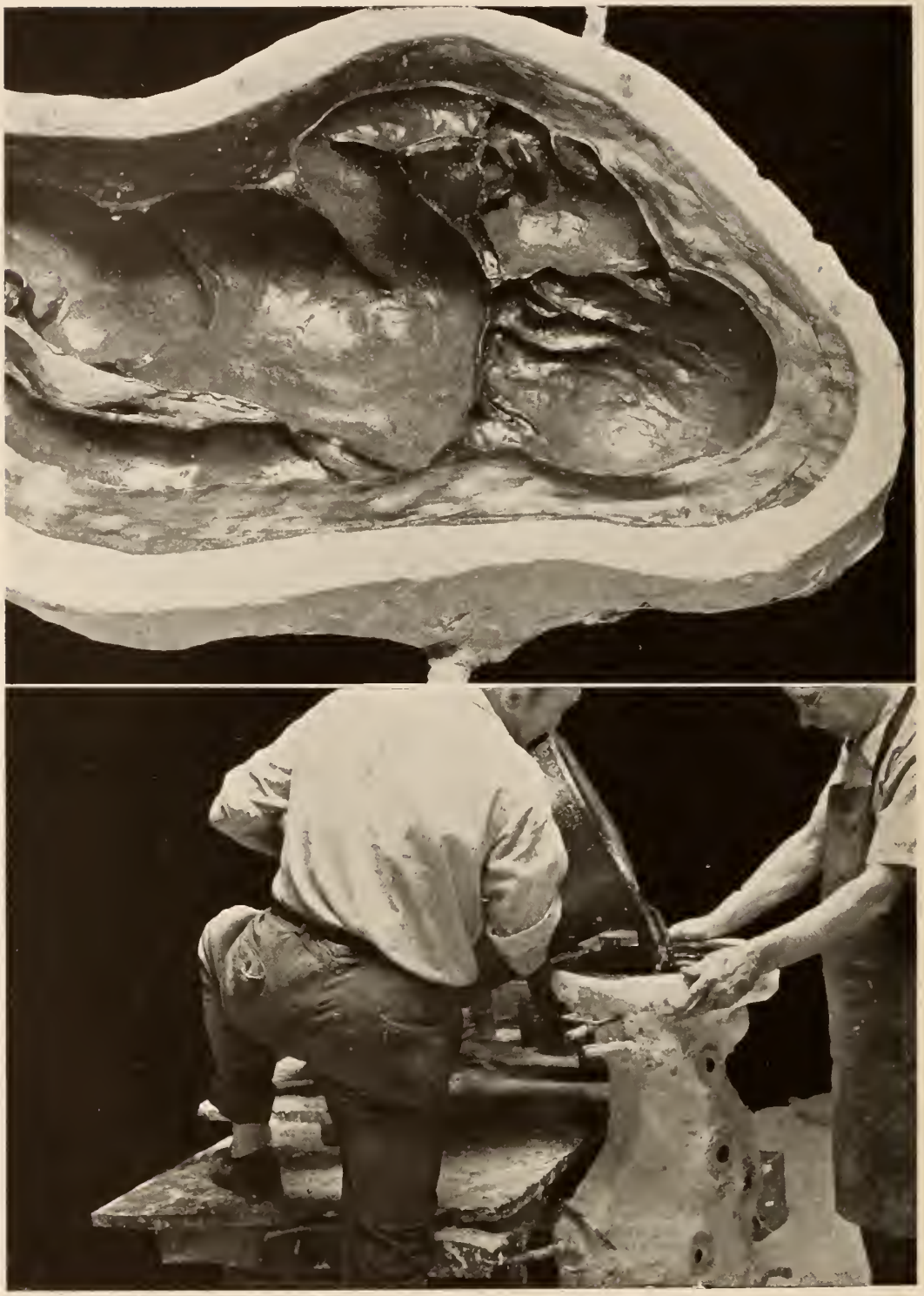

Figure 35. *a,* Rolled cylinders of wax are placed over the raised edges of the mold to prevent the pouring wax from running thin over these areas. *b,* The resin-wax mixture is poured until the mold is full. After the desired thickness has been built up against the surfaces of the mold, the excess wax is poured back into the pot.

pouring. When the wax against the surface of the agar mold reaches the desired thickness, the excess wax is poured back into the pot. This thickness should vary according to the size of the model. The thickness of this wax crust determines the thickness in metal of the final hollow metal cast. The thickness of the wax should vary according to the size of the model and the kind of metal used. For example, if bronze is to be used and the model is only a foot high, the wax deposit should be at least one-eighth of an inch thick. If the model is three or four feet high, the thickness of the wax should be about one-quarter of an inch. If the final cast is to be in lead, the thickness of the wax can be increased slightly to prevent drooping of extended parts in hot weather or because of mechanical pressure. In the event the wax is too thick, the metal may be too porous after setting. When the wax is too thin, the metal will not flow properly and will leave open spaces in the cast. The thickness of the wax in the agar mold can be determined when the mold is filled with the wax by blowing the breath with force into the hot wax-resin mixture on the edge of the mold. The melted wax is blown away from the edge, but the set wax remains. It is then easy to see how much wax has been built up or deposited on the edge by setting to the surface of the agar mold.

The wax is poured from the mold back into the wax pot after sufficient thickness has been built up. If the model has thin supports similar to the legs of the model in these illustrations, the wax must be poured slowly back into the pot. If it is poured too fast, the hollow legs will fill up with liquid wax and thus prevent the air from going into the closed mold as the wax flows out. This creates a vacuum or suction against the inner hollow surfaces of the wax cast and causes the thin soft wax to separate from the mold. If this precaution is not taken, the cast may have a caved-in appearance as a result of this suction when it is finally removed form the mold.

Before the core is poured or the wax removed from the mold, small pieces of wax as seen in Figure 36 *a* are cemented to the inside of the base. When finally transferred into metal these serve as anchors to bolt the figure to its base, which may be composed of marble, cement or stone. If the figure is supported on small legs, as in the case illustrated, it becomes necessary to use copper pipes or rods to support the suspended weight of the core in these areas. Otherwise, the core may crack and fall against the inside surface of the mold after the wax is melted out. Furthermore, the actual force of the metal may cause an unsupported core to break. Iron rods are not suitable, as a crust is formed on them during the baking and it may spoil the luto for further use. Luto is made by powdering the old mold after it is used. It can be employed in new mixtures as about one third of the entire content. A small percentage of iron in bronze causes the bronze to become brittle. Such copper supports are seen in place in Figure 36 *b*.

Figure 36. *a*, The base end of the mold after the wax has been poured out. Semicircular projections of resin-wax have been placed on each side of the base. When these are finally in metal they will be drilled and threaded to hold the metal cast to a base. b, Copper or brass rods are placed in the leg areas of the cast as mechanical supports for the core which will be poured later.

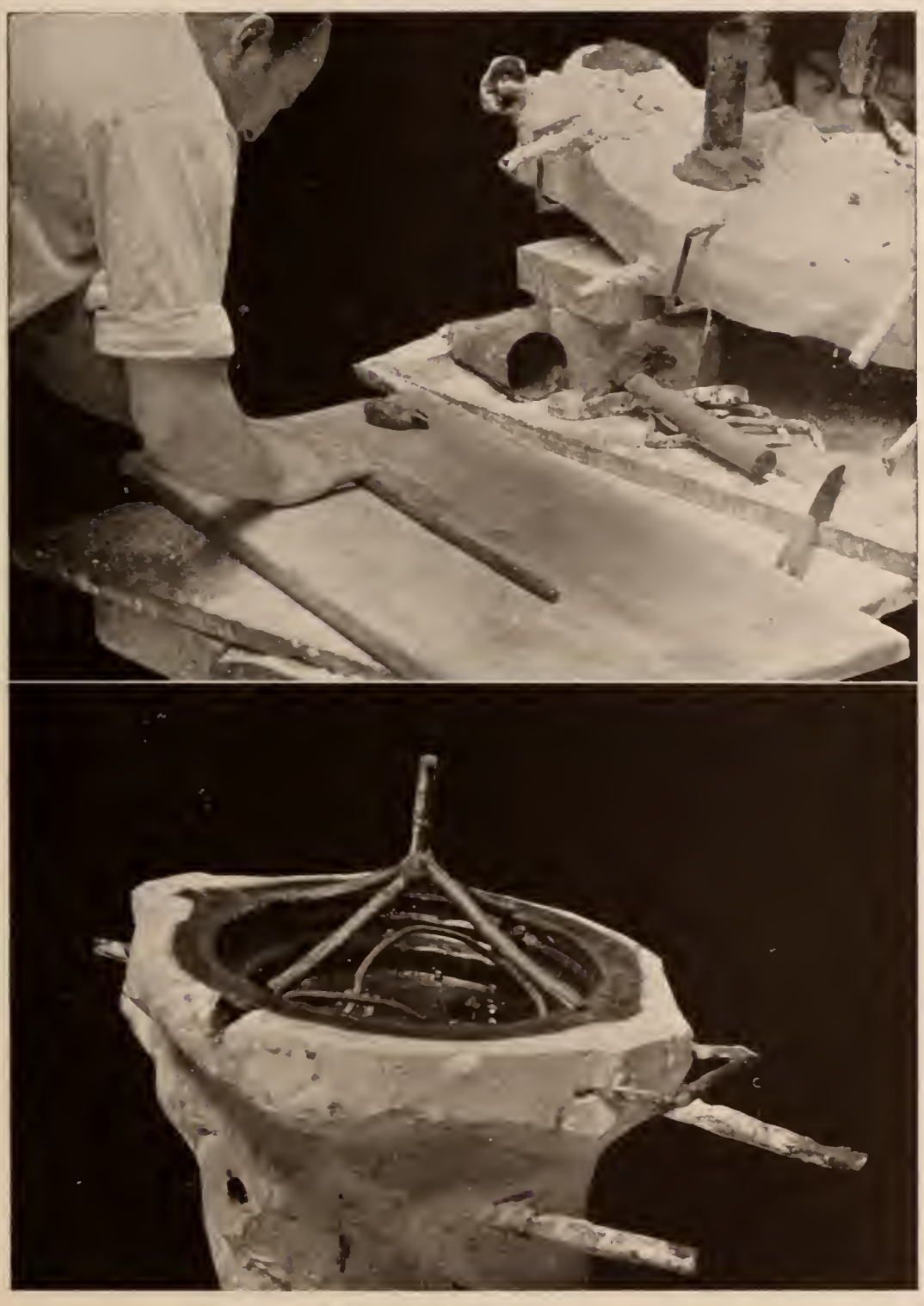

Figure 37. *a,* Resin-wax rods are rolled for forming pouring columns, gates, sprues and vents. *b,* The drain line is added to the base of the wax cast. On heating the invested cast, the wax will flow out of this drain line.

Vents or drain holes for allowing the wax to flow from the mold also must be supplied, as seen in Figure 37 *b*. This is the base of the wax figure which is still encased in the inverted mold. The small ball of wax in the center of the vertical rod of wax should be noted. Later this will create a hollow ball in the plaster-silica mold after the wax has been melted out. This impression of the ball will be stuffed with ordinary cotton fiber after the mold has been baked. In addition, the cotton will be reinforced with clay to prevent the metal, which is poured from the opposite end, from flowing through the mold. The ball shape forms a lock to prevent the heavy metal from forcing the cotton and clay through the opening.

After the legs are supported with copper and the drainage vents attached, the core is poured as seen in Figure 38 *a*. This composition consists of one part plaster, one and one-half parts silica, and one and one-half parts of luto. The cast is not only poured up to the level of the base, but as the core sets, more of the plaster-silica-luto mixture is applied to create a base for the core and mold. The mixture on this base is left quite rough so that it will lock with the mold which is to be applied later.

Formulas for investment compositions are given in Chapter XI.

When the worker has decided upon the formula he intends to use, he may proceed with the making of the core and mold. Generally, the same formula is used for both the core and the mold. However, such ingredients as course grog or luto are eliminated from the formula for a core if the core must be poured through small openings.

After the core is poured, as seen in Figure 38 *a*, and the extended base of the core is built up and has set as seen in Figure 38 *b*, the wax cast, mold and core are turned so that they rest on the base of the core, as seen in Figure 39 *a*. The mother mold or case is opened and both halves are removed. Then the agar mold is removed as seen in Figure 39 *b*. It will be found that a seam remains on the wax cast at the line where the two pieces of the agar mold are fitted together. This seam is scraped off, as seen in Figure 40 *a* and *b*, so that it will not be reproduced on the final metal. Any defects in the wax may be patched or repaired at this stage.

A wall of plaster-silica-luto mixture is built up around the base to hold the thin molding mixture that flows from the cast when the mold finally is applied to the piece of sculpture. This wall or well is shown in Figure 40 *d*, which should be compared with Figure 40 *a*. Before the molding mixture is applied to the model, the pouring columns for the metal are added, as seen in Figures 41, 42 and 43. Gates are connected to these columns every four to six inches apart, so that the metal will not chill during the flowing. These gates are used to direct the metal evenly all over the entire pattern. In addition to the

Figure 38. *a*, The core is poured. *b*, The core is built up to the end of the drain line. The worker is pointing to the end of the drain line imbedded in the core.

Figure 39. *a*, The mold is turned so that it rests on the built up core and the mother mold is removed. *b*, The mold is removed, leaving the wax cast over the core.

Figure 40. *a*, The join line formed at the junctions of the two halves of the mold is scraped away. *b*, The wax cast can be retouched with wax at this stage. Only minor changes can be made. Generally this is done by the sculptor. *c*, The core nails are driven into the wax cast for anchoring the investment mold to the core. *d*, The investment mold is begun by forming a cup around the extended core at the base.

pouring columns and gates, air vents or sprues to take off the gases created by the molten metal also must be added. These may be placed at convenient points, especially the places that will create air pockets. If an air vent is not placed in such a pocket, the gases will be caught in the pocket and compressed to such an extent that a minor explosion may occur within the mold and result in a defect such as a hole in the final metal cast. Risers or air vents, pouring columns and gates may be seen in Figures 41, 42 and 43. These rods are made of three parts resin to one part of ceresin or a microcrystalline wax. Such a mixture is only suitable for winter weather, as these rods droop readily in warm weather. To prevent this drooping one part of carnauba wax or a high-melting point micro-crystalline wax should be added to every ten parts of the resin-wax mixture. If the mixture is too brittle or has a melting point that is too high, it can be reduced by adding petroleum jelly to the mixture.

In addition to the columns, gates and vents, a wax pouring cup or funnel, as seen in Figure 43 *b*, is provided to create a space in the mold to receive the hot metal. This cup is made by pressing the soft resin-wax mixture into a bowl or pan of the desired shape. Of course, a mold especially for the purpose of casting these cups could be made if desired. This cup is attached to the top of the pouring columns by heating the bottom with a soldering iron until the wax melts sufficiently to hold the cup in place.

After the pouring columns, gates, air vents and the funnel are in place, the wax cast can be brushed or sprayed with alcohol or a wetting agent such at *Aerosol** to prevent the formation of air bubbles in the plaster-silica investment compound. The investment mixture to form the mold is then applied. In the case illustrated a thin mixture of one part of plaster to one and a half parts of silica was mixed and used on the whole mold as a first coat. The entire surface should receive the mold mixture before it sets, for if it is allowed to set on part of the surface and then another mixture is added to cover the remaining parts of the model, a seam or fin may appear on the bronze cast at the juncture of these two applications. After the first application has set, more is mixed and applied. This second application may be coarser and contain considerable luto or grog. In the case illustrated, the second and succeeding applications contained one part of plaster, one and one-half parts of silica, and one and one-half parts of luto. These were mixed and applied over the first coat, which was composed of plaster and silica only. In this manner the mold is built up to the desired thickness, as seen in Figures 44 *a*, *b*, and *c*.

After the mold is completed it should be moved immediately to the baking oven. If allowed to set for a few days, it will dry out and

* Manufactured by Eimer and Amend of New York City.

Figure 41. *a*, The pouring columns and gates are put in place before the investment mold is applied. *b*, The pouring columns can be sealed together with hot tools.

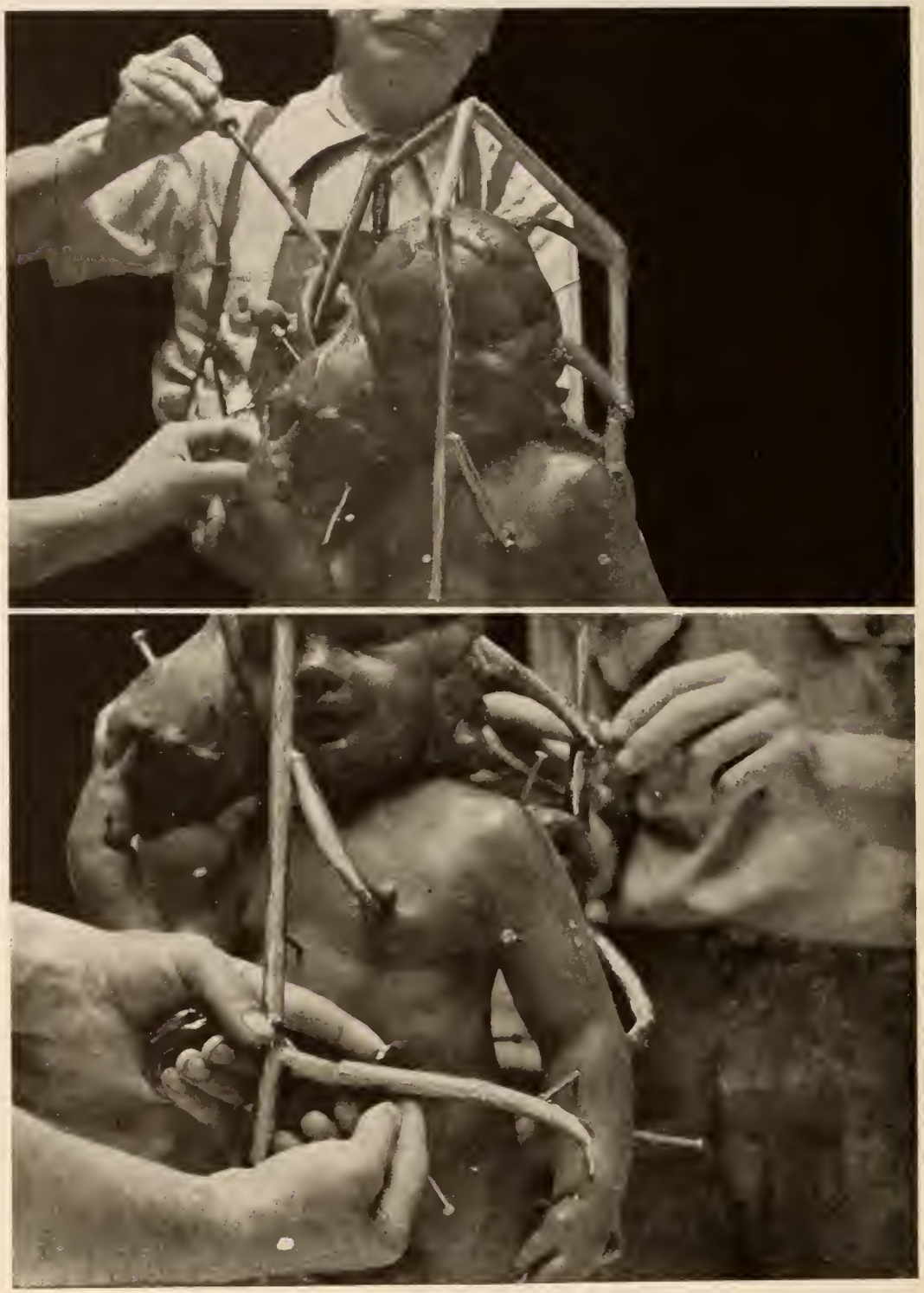

Figure 42. *a,* The pouring columns and gates begin to take shape. *b,* Gates are applied in such a manner as to allow the hot metal to run freely over the entire cast without chilling. They may be joined together with some of the warm resin-wax mixture.

Figure 43. *a*, The pouring columns and gates from the rear of the wax cast. *b*, The pouring funnel of wax is attached at the top of the pouring columns. *c*, The investment mold is begun by applying or "throwing" a thin mixture of the investment compound directly to the wax cast. *d*, This is continued with thicker mixtures until the mold begins to take shape.

probably crack. In the event it becomes desirable to hold one mold until another is finished, which may take a few days, water should be sprinkled on the first mold to prevent drying. Because of its fragility the mold should be handeled carefully when it is moved to the baking oven. A crane and chain hoist are practically essential for this purpose if the mold weighs two hundred pounds or more.

The baking oven is constructed of brick. A groove or channel is made through the center of the oven, into which is inserted a long piece of V-shaped tin or a gutter to collect the wax as it melts and flows from the mold. Mortar is not placed between the bricks unless the oven is quite large, which is necessary if the oven is to take an eight foot figure. In such a case it must also be of heavy construction. After the base of the oven is made, the mold or molds are put in place carefully so that the point from which the wax is to flow on melting is directly over the channel that runs between the bricks upon which the mold rests. When placing the mold on this support a folded piece of paper is stuck to the wax in the opening from which the wax flows. The worker can easily see this piece of paper as he bends over and looks up the channel between the bricks (Figure 45 *b*). Before the walls are built to the proper height, bricks are placed over the funnel-shaped opening and the vents on top of the mold, so that dirt will not enter these orifices as the wax melts out at the bottom (Figure 46 *a*). A mixture of clay and luto is used around the bricks to help prevent the entrance of foreign material and to hold the heat in the mold (Figure 46 *b*).

After the mold is in the proper place and the brick walls are built to the correct height, a piece of iron may be placed over the top to support a tin roof. If this is not done, the tin top may sag under the heat which will later be created in the oven. The tin top is used to hold the heat in the oven. Bricks are then placed on top of the tin roof to hold it down. Naturally, these bricks are placed on the tin directly above the brick walls; if placed in the middle, the top will sag when heated. In addition to this top, a mixture of clay or mud and luto is used to cover the bricks to hold them together and to keep the heat from escaping.

The heat for baking molds may be supplied from a number of sources. The old metal workers used wood, whereas the modern foundry uses either gas or oil, but coal or coke will serve the same purpose. Both the coal and coke produce sulfides in combination with the plaster, thus materially weakening the surface texture. The fuel used in the oven shown in Figure 46 is gas, supplied from two large cylindrical gas burners placed in channels on each side of the molds. In reality the base of the oven has three channels (Figure 45 *a*), two for the gas burners and one for the wax to flow out into the pan placed at the end of

Figure 44. *a*, The investment mold is rounded off at the bottom as it progresses upward. *b*, Vent lines are added to the pouring columns as the mold develops. *c*, The completed mold. d, The mold is tied with rope for moving into the drying oven.

Figure 45. *a,* The mold is moved into the drying oven which is built around the mold or molds. Notice the division between the bricks for supporting the molds. *b,* The exterior end of the drain line must be centered over this division. The worker is centering this by studying the investment mold from below.

Figure 46. *a,* The bricks to form the drying oven are laid. *b,* These bricks are covered with mud to hold the heat within the oven. A v-shaped piece of tin or a gutter is placed in the division between the brick supports to catch the wax as it drains from the mold. A pan is used as a recepticle. This resin-wax mixture can be used again. Seldom is more than fifty percent recovered; the remainder is consumed.

a tin trough to carry the melted wax (Figure 46 *b*). This trough should be placed at an angle to the base so that gravity will cause the wax to flow into the pan. The foundry supplying common commercial bronze and brass castings may have core ovens of sufficient size to bake statuary molds. If such ovens are available, the brick furnace herewith illustrated may be eliminated. However, it is advisable to provide some method of draining the wax from the mold instead of having it consumed in the oven.

In large molds of the size pictured in the illustration and larger ones it takes from one to three days to melt out the wax completely, dry the mold, and burn up or carbonize any wax that may soak into the mold. All of these procedures are necessary before the mold can be poured with metal. Of course, the time may be varied according to the size of the mold and the type and intensity of the heat used.

When the mold is ready to receive the metal, it may be tested before the fire is extinguished. At some time during the curing of the mold it will catch on fire at its base, at the top, or both places. This can be observed through one of the ventilation holes in the base of the oven or one brick may be removed with tongs to observe the burning wax. This brick should have been so placed during the construction of the oven that it can be removed easily without causing the other bricks on the mud-luto casing to fall. The fire in the vents is caused by the vaporizing of the melted wax from the porous mold. When the water is expelled from the mold, some of the wax is absorbed in its place. At this time the wax-resin mixture is generally at a temperature above its flash point, therefore it ignites. Eventually the flame burns out, but the drain vent may continue to give off wax and water vapors. The fire around the mold should not be extinguished until both the fire and vapor cease to be expelled. Even then the mold should not be removed from the oven until it is tested fully for wax gases in the following manner.

A long, thin, quarter inch pipe with a six inch right angle bend on one end is inserted into the channel provided for the wax to flow out. The end of the bend is pushed through the hole at the bottom of the mold. The other end is placed in the worker's mouth. He blows air into the mold to expel the gases from the pipe and to see that the pipe is not stopped up. Then he draws some of the air into his mouth directly from the inside of the mold. If smoke or wax fumes enter his mouth, the mold is not ready for the metal. The air should feel hot to the mouth but have no taste and contain no smoke.

After the heat is turned off or permitted to die out, the mold is allowed to stay in the closed oven for at least eight hours or more for gradual cooling. This depends on the season of the year and the temperature of the room. Should the oven be opened during this time, the cool air would rush in and crack the mold as a result of contraction. At the

end of such a time, when the oven is opened, the mold often feels warm to the hand. This warmth is not essential, but the mold should be thoroughly dry in any event. In other words it should not be allowed to remain in the oven long enough to begin to absorb moisture from the air. Large molds actually may be hot in the inside twenty-four hours after the fire is extinguished.

The mold is removed when the oven has cooled. While it is still supported on the crane, part of the hole from which the wax flowed is packed with cotton fibers and the remainder of the opening sealed with damp clay. This clay is forced in with a piece of wood or with a metal rod. Figure 47 *a* shows the pit into which the mold is placed for the pouring of the metal. At the top of this illustration is shown a piece of paper on which are the cotton and the damp clay for ramming into the hole. The worker in Figure 47 *b* is ramming this hole with cotton and clay. The mold is then lowered into the pouring pit. The bottom of this pit should not be wet, but damp and rammed tight. The dampness of the earth can be tested by squeezing a handful. If water comes from in between the fingers, it is too damp; if after squeezing it the wad within the hand falls apart of its own accord, it is too dry. The wad should be firm and hold its shape. If it is too wet it soaks the mold and becomes dangerous, because the hot metal coming in contact with the wet mold creates steam which blows the metal back through the pouring funnel and into the air. It may also crack the mold. A small amount of moisture in the mold causes the metal to boil and thereby ruin the surface of the cast.

Damp earth is then rammed and packed around the mold until it is firm. This prevents the mold from cracking as a result of expansion caused by the heat and weight of the metal. During this filling in and packing of the dirt a large piece of paper is placed over the top of the mold and weighted down with a flat board to prevent dirt and dust from getting into the pouring funnel, columns and air vents. (Figure 48 *a* and *b*.) This is removed carefully just before the metal is poured. Generally two or more molds are placed in the pit at the same time and poured one after the other. Care must be taken in advance in filling the space around the molds, so that they will not expand during the pouring because of the heat and weight of the hot metal. Large timbers are placed around the mold as a precaution. A molder's flask could be used for this purpose, thus reducing the size of the space around the mold and making the use of timber unnecessary. However, it is often difficult to keep on hand enough molder's flasks to fit every mold. This method would be more suitable when the molds run uniform in size. The timbers or flasks take up space and require less dirt for packing around the mold or molds. If timbers are used they must not be forced against the molds, as they may crack the mold and cause a faulty casting.

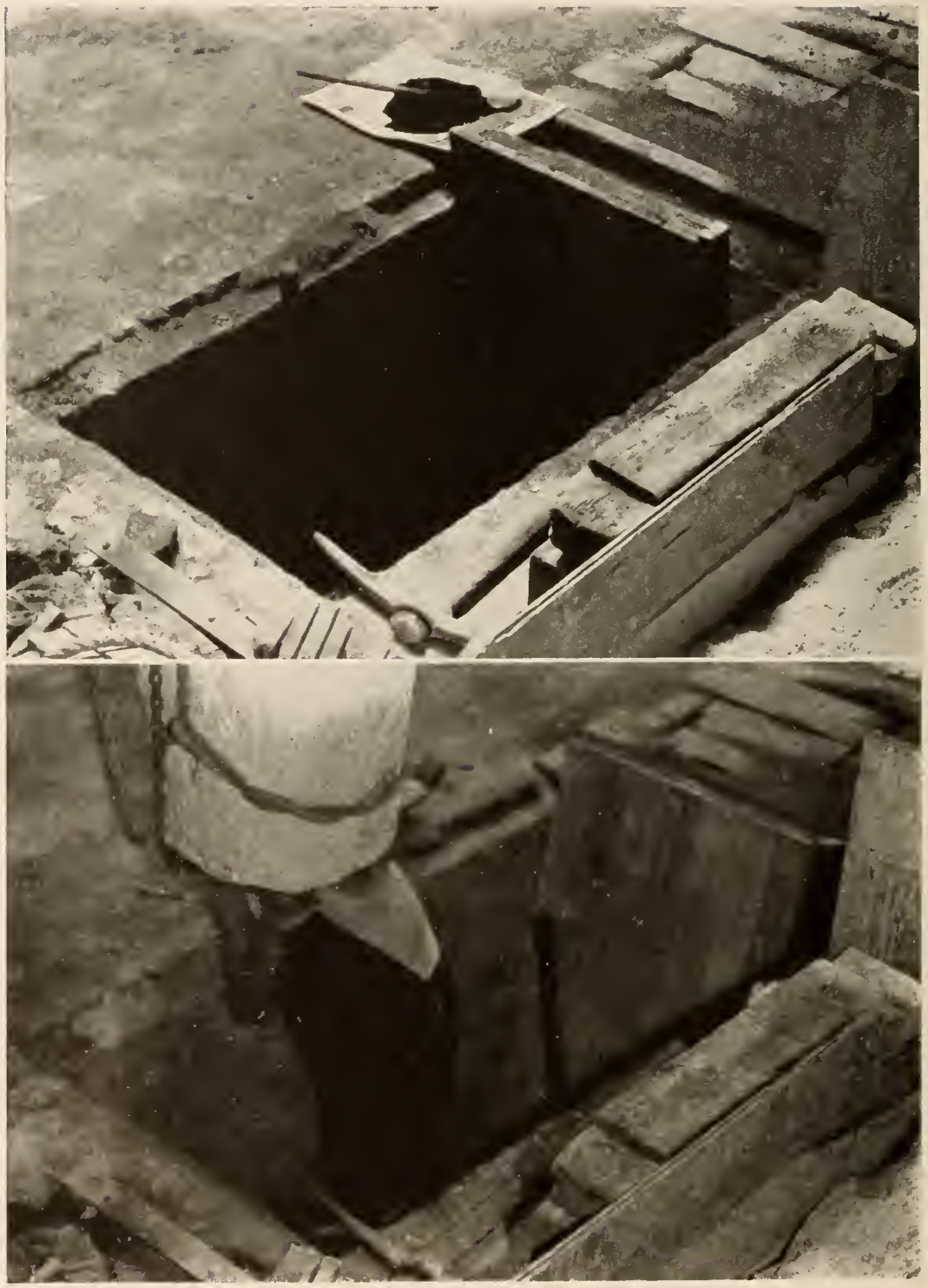

Figure 47. *a,* The pit is prepared to receive the dry mold. Notice the piece of cotton, some earth and a ramming stick on the piece of paper at the top of the illustration. *b,* The worker places the cotton in the open drain line and then forces earth against it with the stick, so that the hot metal will not continue to run through the mold. The cotton is consumed by the hot metal.

Figure 48. *a*, The molds are set in place within the pit. Care is taken to keep the funnel openings free from dirt at all times. At this stage they are covered with paper and boards. *b*, Timbers can be placed within the pit to fill space and prevent too rapid expansion of the mold when the metal is poured.

Figure 49. *a*, Earth is then packed and rammed around the mold. *b*, The worker sees that the pouring opening is clean before the metal is poured. In this case, he has kept a piece of cotton within the funnel to keep out dirt.

When the timbers are in place, a little earth is shoveled into the pit and packed, then more earth is added and packed (Fig. 49 *a*). This is continued until the earth reaches within a few inches of the top of the mold. The dirt is carefully cleaned from the top of the mold and the newspaper, and a few bricks or a flat board replaced to keep the opening clean until the metal is poured. The worker in Figure 49 *b* is shown lifting the piece of paper covering the pouring hole. In his left hand he holds the piece of cotton that was placed in the funnel to keep out the dirt. In the meantime the metal is melted for pouring. The cotton is removed from the funnel-like opening, and the metal is poured into the mold.

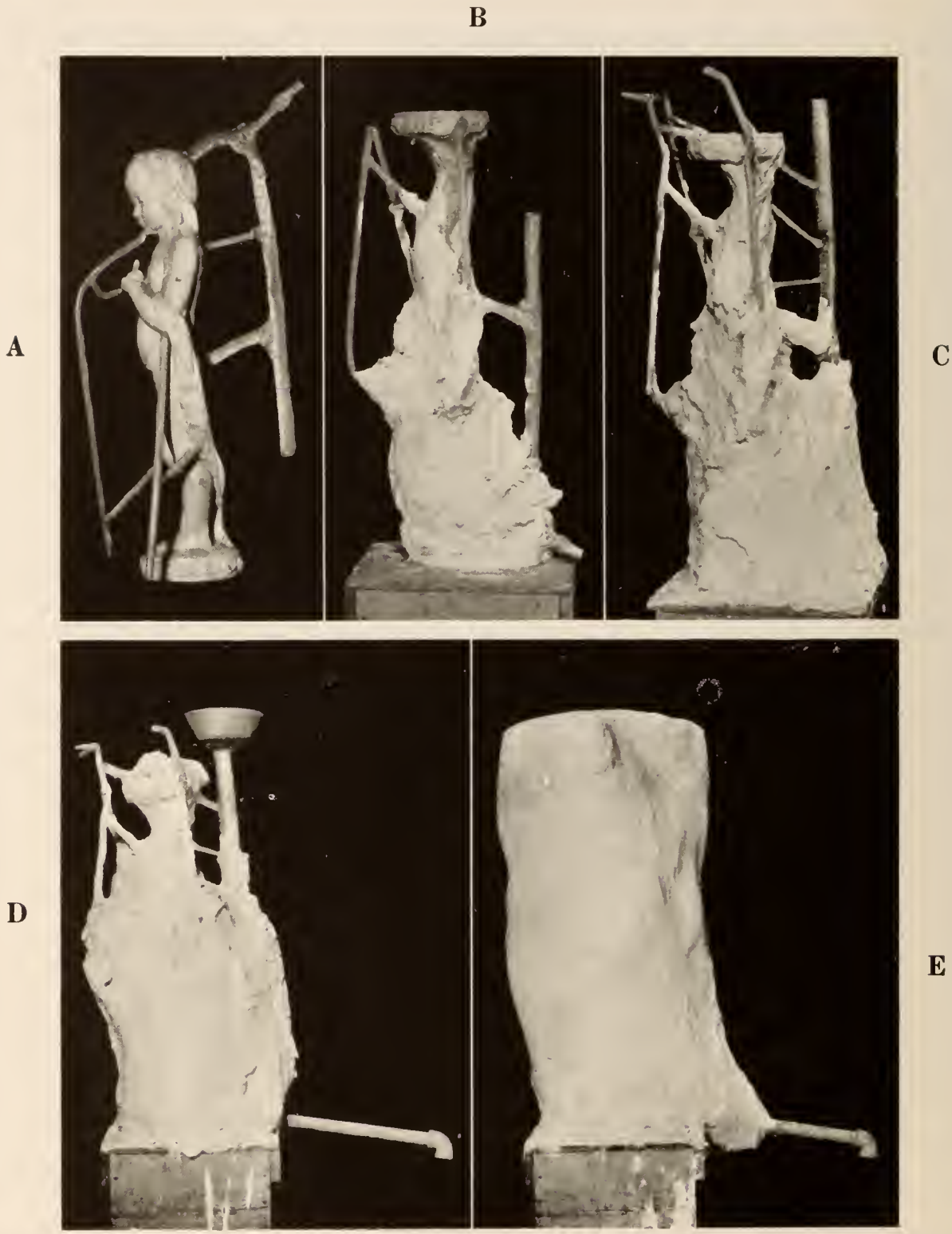

Figure 50. *a*, Small well-supported figures may be vented before the core is poured. *b*, The mold is built up around a single pouring column. Notice that the drain line is added at the end of the pouring column. *c*, The pouring column sprues and gates can be extended or added as the investment mold develops. *d*, The pouring funnel and metal pipe drain line can also be added as the mold develops. *e*, The mold on nearing completion.

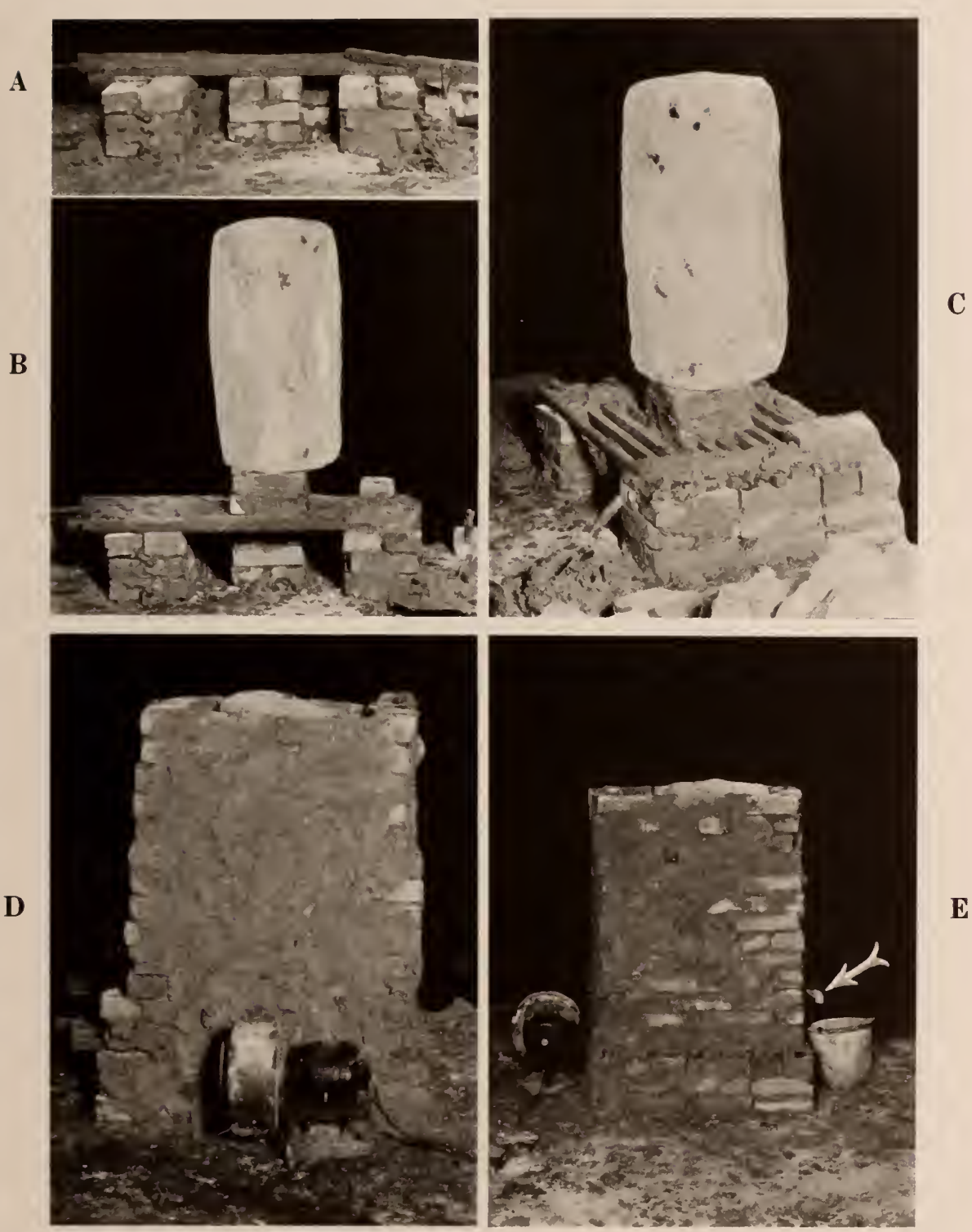

Figure 51. *a*, Starting a coke drying oven, using an iron grate. *b*, The completed mold placed on the support on the grate. *c*, The drying furnace is built up of bricks and mud. *d*, The furnace nearing completion. It may be fed from above. *e*, A blowing fan is used to speed up the drying. *f*, The arrow points to the metal pipe extension for draining the melted resin-wax mixture from the mold. This is collected in a bucket.

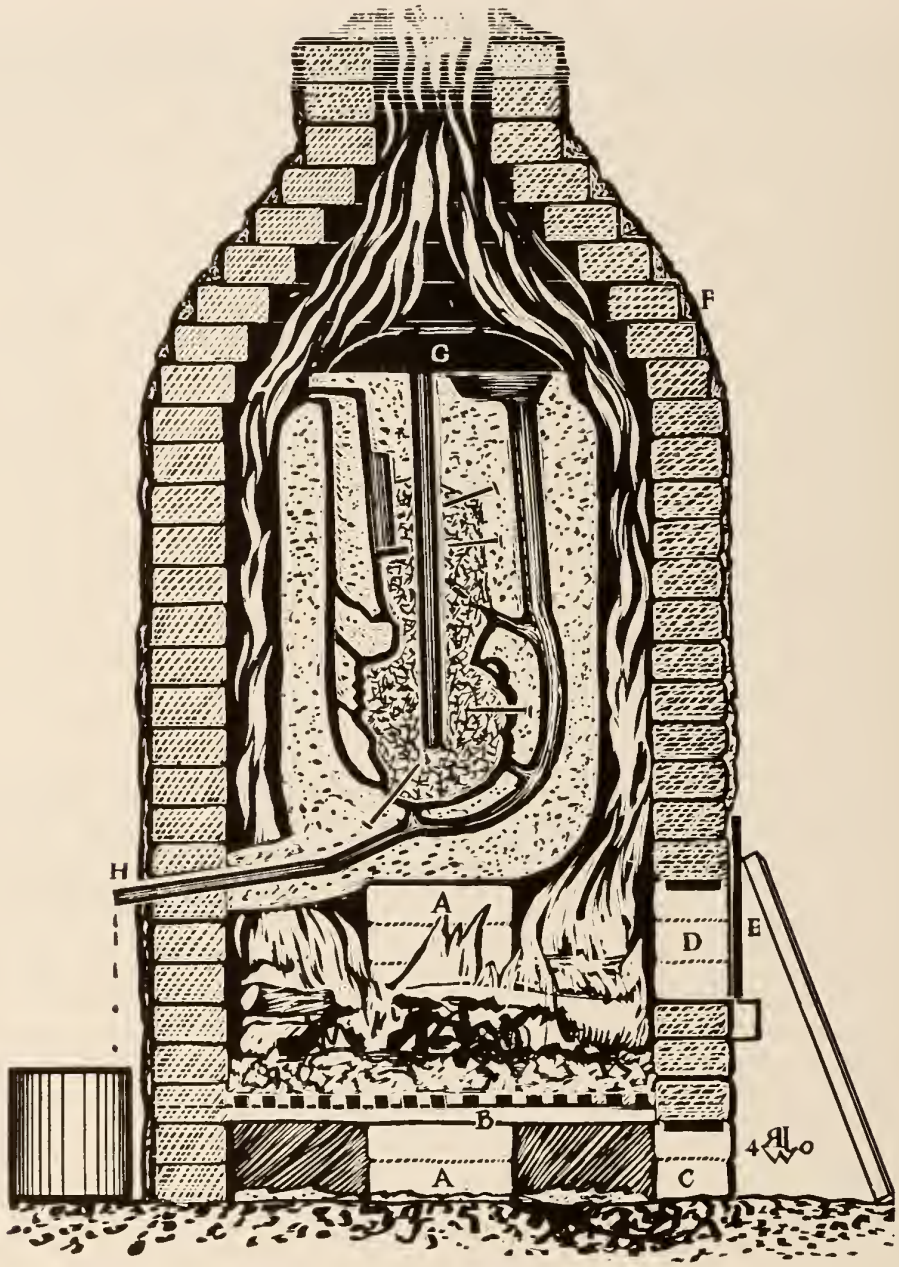

Figure 52. A diagramatic view of such an oven, showing an invested portrait head. A schematic section of the mold in the furnace for baking. In order to show that the fire completely surrounds the column, the section at the grate bars has been taken at a plane 9 inches nearer the spectator than the section through the mold iself. *a*, The fire-brick column supporting the mold. *b*, The grate, surrounding the column on four sides. *c*, Ash-pit opening (ashes should be cleared out frequently to prevent obstruction of draft). *d*, Fuel door, matched by another on the opposite side of the column and closed by a cast iron plate (*e*) resting on projecting bricks. *f*, Bricks roughly built to follow the shape of the mold, with a 3-inch flame passage, and covered with mud. *g*, A cast iron cover to protect the pouring mouth and sprue from dirt and ashes (an iron stove lid can be used for this purpose). *h*, An iron pipe luted to the drain from the mold and protected with molding investment. A can placed under the pipe, outside the furnace, saves the wax that is not absorbed by the mold and core. The pipe may be removed when the wax entirely ceases to flow (its covering having been broken off with a poker) and a loose brick used to stop up the hole in the furnace wall. This is removed from time to time to permit observation of the flame which burns from the drain hole. A similar aperture may be used in watching the upper openings. *Courtesy Randolph Wardell Johnston, Technical Studies.*

Figure 53. *a,* Three stages in the final removal of the investment mold and finishing. *Left,* The investment nearly removed. *Center,* The completely removed investment. Finishing has been begun. *Right,* The patined cast. *b,* Scrapers, wire brushes, hammer and chisels, files and plaster tools are used in the final hand finishing of metal casts.

CHAPTER XIII

METALS AND THEIR ALLOYS

There are many different metals and their alloys that are suitable for nonferrous metal casting. It is seldom that a pure metal is used for the cast; an alloy is employed instead. Alloys are the result of melting together two or more metals, such as nickel, copper, aluminum, zinc, lead and tin. They generally possess characteristics not shared by their component metals. Thus, copper and zinc form brass, which has a density, hardness, and color different from either of its constituents. In the same manner, copper, tin and zinc form bronze. However, the word *bronze* is a rather loose term which is applied to alloys composed of varous metals, such as copper, tin, aluminum and zinc. Genuine bronze consists of copper and tin. The greater proportion of the mixture is usually copper, regardless of the other metals used in the alloy. Many metals can be alloyed to form various types of alloys of different colors and used for different purposes.

FUSIBILITY AND WEIGHT OF METALS

	Melting Points Degrees Centigrade	*Melting Points Degrees Fahrenheit*	*Specific Gravity*	*Weight in Pounds Per Cubic Inch*
Aluminum	654.5	1230.0	2.7	.09
Antimony	630.0	1200.0	6.67	.24
Arsenic	450.0 (Under pressure at 850.0. Volatises about 100 C. Sublimes at 616 C.)		4.7 to 5.7	.20
Barium	850.0	1562.0	3.46	.135
Bismuth	270.0	518.0	9.78 (20C.)	.34
Cadmium	320.0	608.0	8.642	.30
Chromium	2000.0	3632.0	6.92	.25
Cobalt	1500.0	2732.0	8.5 to 8.9	.31
Copper	1083.0	1981.0	8.90	.31
Gold	1120.0	2012.0	19.30	.696
Iridium	2300.0	4172.0	22.42	.809
Iron—				
Cast	1250.0 to 1300	2300 to 2350		
Gray	1200.0	2192.0		
Malleable	1149.0	2100.0		
Pure	1600.0 to 1804	2913 to 3400	7.86	.28
Lead	326.0	618.0	11.33	.386
Magnesium	800.0	1472.0	1.69 to 1.75	.062
Manganese	1242.0	2268.0	7.20	.26
Mercury	−39.44	−8.55	13.5933	.491
Nickel	1450.0	2632.0	8.9	.31
Osmium	2500.0	4532.0	22.48	.81
Palladium	1500.0	2732.0	11.4 to 11.8 at 15C.	.38
Platinum	1753.0	3200.0	21.45	.714

Rhodium	1946.0	3524.0	Density 12.44	
Silver	960.0	1760.0	10.50	.37
Tantalum	2770.0	5018.0	Density 16.6	
Tellurium	452.0	845.0	6.25	
Tin	232.0	450.0	7.29	.263
Tungsten	3100.0	5600.0	19.10	.69
Zinc	415.0	779.0	7.142	.254

Every pure metal has a specific melting point, as shown in the table above. This is of importance in compounding alloys, because as a rule the one having the highest melting point is melted first. The other metals are added according to their melting point to prevent the volatization of metals of lower melting points. The resulting alloy will invariably have a melting point different from any of its component metals. In fact, it is possible to mix two or more metals into an alloy with a resulting melting point lower that the metals used to make the alloy.

Oxidation should be guarded against in the melting of base metals or alloys. Various methods are employed for this purpose. The most common is to cover the metal with a carbon, such as charcoal. This not only excludes the air admitted to the crucible, but tends to absorb any oxygen liberated to the metals during fusion.

It is a well-known fact that the character of many alloys is altered by repeated remelting and that the scrap obtained in working cannot be used again without the addition of new metal. A definite mixture may be employed for the formation of an alloy which is highly malleable, ductile and tenacious, whereas the scrap remelted from the same alloy may be brittle and unworkable. When a suitable quantity of new metal is added, the combination may produce an alloy with good working properties which are even superior to those of the original. It is of advantage from an economical stand-point for the worker to use his scrap metal. To the metal caster of sculpture this is in the form of gates, columns and sprues from previously cast subjects. The quantity of scrap metal employed in a new mix may vary from one-third to two-thirds of the weight of the entire charge. When incorporating scrap into a charge, it is likely that impurities are introduced, but these will probably not be sufficient to produce a deteriorating effect. The presence of noticeable quantities of foreign matter is usually detected by increased hardness and a modification of the structure, as seen on a freshly fractured surface.

Bronze, an alloy, is composed of copper and tin, with a little zinc and sometimes a small quantity of lead, as previously mentioned. It is harder and more fusible than copper alone. It oxidizes slowly, even when the air is moist, and this renders it satisfactory for statuary. Genuine bronze, which is composed of copper and tin alone, is hardened

by the addition of zinc and lead. The result is a product between true bronze and brass. The reason for the use of such mixtures lies partly in the fact that their production is less expensive as compared to real bronze and the fact that genuine bronze, however strongly heated, does not become thin enough to fill out the mold properly and does not produce a homogeneous casting. Brass alone flows too sluggishly and is not had enough for the required fine chiseling or chasing of the finished object with files and chisels.

The best proportions are as follows:

Copper	78 to 88 per cent
Zinc	10 to 18 per cent
Tin	2 to 4 per cent

The following is an excellent alloy for bronze castings:

Copper	Tin	Zinc	Lead
85	5	5	5

This composition, as well as similar mixtures, may be purchased in ingot or pig form.

Too much tin makes the alloy brittle and difficult to chisel; too much zinc causes the resulting cast to lose its warm tones, and it will not acquire a fine patina. Lead in the bronze mixture produces a soft cast and if large quantities are used, the surface will sweat and be pitted; however, it increases the flowing quality of the molten metal.

The following table is a series of alloys of different colors suitable for statuary purposes:

Copper	*Zinc*	*Tin*	*Color*
84.42	11.28	4.30	Reddish yellow
84.00	11.00	5.00	Orange red
83.05	13.03	3.92	Orange red
83.00	12.00	5.00	Orange red
81.05	15.32	3.63	Orange yellow
81.00	15.00	4.00	Orange yellow
78.09	18.47	3.44	Orange yellow
73.58	23.27	3.15	Orange yellow
73.00	23.00	4.00	Pale orange
70.36	26.88	2.76	Pale yellow
70.00	27.00	3.00	Pale yellow
65.95	31.56	2.49	Pale yellow

Lead and its alloys are important metals for making sculptural figures. The following mixtures produce sharp, delicate castings:

	I	*II*	*III*	*IV*
Bismuth	6	5	2	8
Tin	3	2	1	3
Lead	13	3	1	5

These alloys expand considerably on cooling and fill out the finest elevations and depressions of the mold. The melting points of these mixtures are as follows:

Bismuth	*Lead*	*Tin*	*Melting Point Centigrade*	*Melting Point Fahrenheit*
8	5	3	100.0	212.0
8	8	4	113.3	235.9
8	8	8	122.7	253.0
8	10	8	130.0	266.0
8	12	8	132.4	270.3
8	16	14	143.0	289.5
8	16	12	149.2	300.6
8	22	24	153.7	308.8
8	32	36	160.2	320.3
8	32	28	167.6	331.7
8	30	24	172.0	341.6

LOW FUSING ALLOYS

	PARTS BY WEIGHT					*Melting Point*	*Melting Point*	
	Antimony	*Lead*	*Tin*	*Cadmium*	*Bismuth*	*Deg. F.*	*Deg. C.*	*Given Name*
1.	0	20	40	26	96	135	57	Wood's
2.	0	3	2	2	5	140	60	Molyneau's
3.	0	2	1	1	4	155	68	Wood's
4.	0	5	5	4	11	162	72	Merck's
5.	0	4	4	1	7	180	82	Harber's
6.	0	5	5	1	8	190	88	Crouse's
7.	0	1	1	0	2	199	93	Erman's
8.	0	5	3	0	8	202	94	Richman's
9.	0	1	1	0	2	203	95	Rose's
10.	0	3	5	0	8	205	96	Melotte's
11.	0	2	3	0	5	212	100	Neuton's
12.	0	5	5	0	3	212	100	
13.	0	11	10	0	12	240	116	Brophy's
14.	2	5	3	0	8	244	118	Hodgen's
15.	0	1	1	0	1	257	125	
16.	0	2	2	0	1	288	142	
17.	0	28	30	0	5	311	155	
18.	0	20	24	0	5	335	168	
19.	0	6	4	0	1	347	175	
20.	0	1	1	0	0	370	188	

NOTE: The metals have to be melted according to the order in which they are named. For example, the antimony is melted first. When this is completely fused the lead is added, then the tin, then the cadmium and finally while constantly stirring the mixture the bismuth is incorporated. The heat should be kept low when the bismuth is added.

DIE AND COUNTER METALS

Die Metals

	Copper	*Antimony*	*Zinc*	*Tin*
1.	3	0	39	8
2.	6	3	48	10
3.	0	0	50	50
4. (Haskell's)	1	2	0	8

Counter-Die Metals

	Lead	*Tin*	*Bismuth*
1.	4	1	0
2.	3	1	2
3. (Haskell's)	5	1	0

CHAPTER XIV

FURNACES

There are numerous types of furnaces for melting nonferrous metals. The early Italian metal casters used wood and charcoal as fuel. Actually these are poor materials for melting metal. Today electricity, gas, oil, and coke are used. Electricity is only recommended for a few of the non-ferrous products, such as copper, nickel and monel metal. Electrical equipment is not recommended for melting brass, bronze, lead, aluminum and most of the other non-ferrous metals.

The coke-fired furnace is probably less expensive to construct. It has grates upon which rest a few fire bricks to hold the crucible. The crucible is placed on these bricks before the fire is started. The fire is then built around the crucible. There should be a good draft through the fire. In most cases an electric cylinder blower or fan is used to create a hot fire and to speed up the melting of the metal. The air is carried to the space beneath the grates by a pipe from the blower or fan, which is kept at a sufficient distance from the fire to prevent overheating of the fan. These furnaces are shown in the illustrations.

The oil and gas-fired furnaces also have blowers to speed up the melting of the metal. Whereas the construction of the gas-fired furnace is less expensive, the oil-fired furnace costs less to operate. The air in the oil-fired furnace mixes with the oil which enters the combustion chamber against a block of refractory material or bricks upon which rests the crucible.

From the illustration shown the worker can learn about the construction of a furnace for melting non-ferrous metals or he may purchase a furnace from a manufacturer.

The Whiting Corporation of Harvey, Illinois, manufactures an economical standard coke-fired brass furnace (natural or forced draft). This furnace consists of a circular steel-plate shell, with cast-iron top and dome cover, and cast-iron grates. The base is fitted with a removable ash pit door, which is closed tight for forced draft. It is designed to take a three inch lining. The price of the furnace does not include the lining. This is a time-tested design, widely used in small or jobbing foundries. Gas-pipe grates may be substituted for cast-iron grates. If preferred, a steel-plate cover will be substituted for the cast-iron cover without additional cost.

Foundry vocational schools must use a safe and efficient melting furnace to prevent accidents to the student and produce desired results at a reasonable cost. These schools buy equipment that is up to date in every respect. The Hausfeld furnace serves well for this purpose.

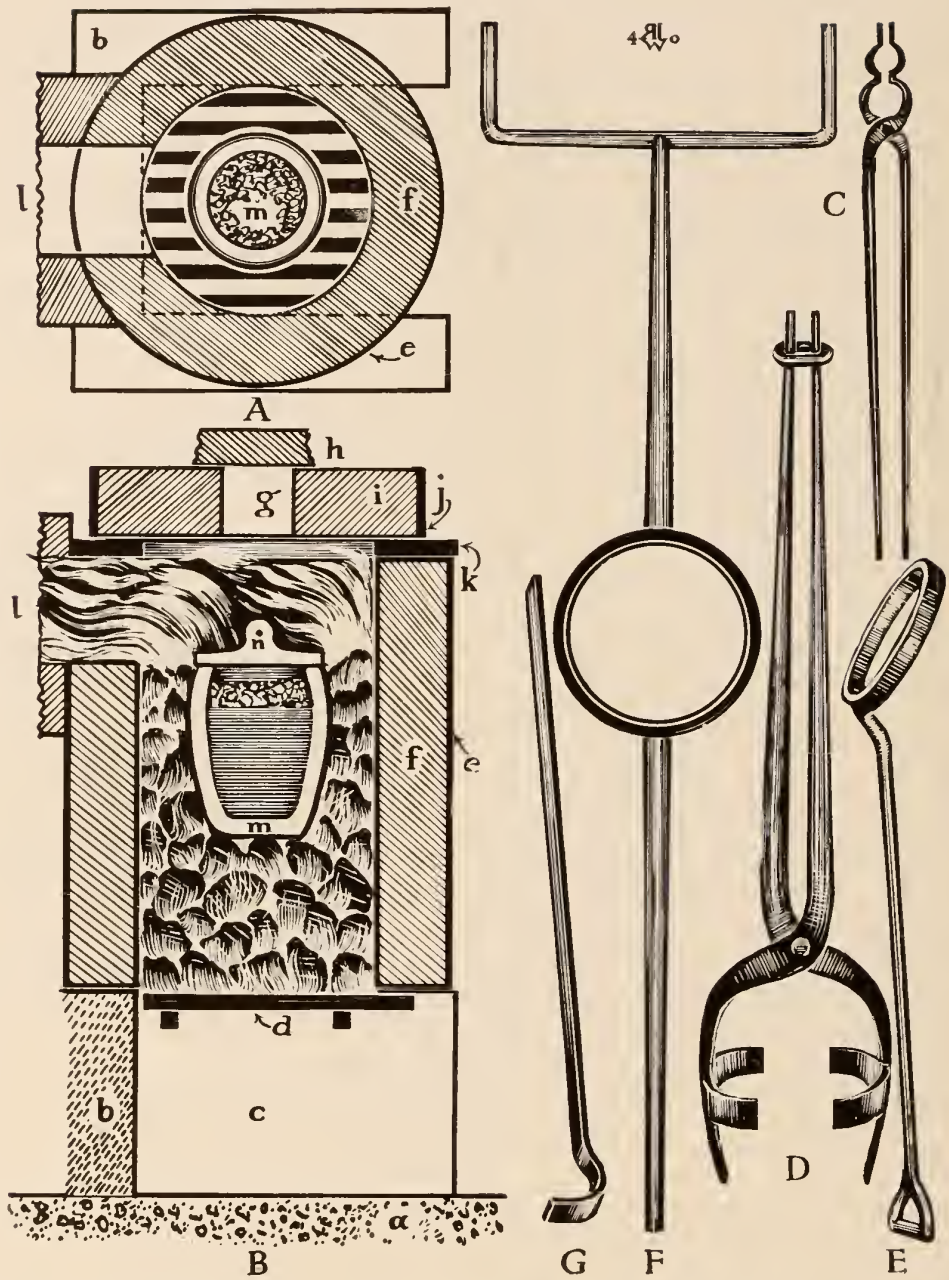

Figure 54. The melting furnace and tools. *a*, Plan of the furnace showing the position of the crucible. The coke has been omitted from the plan to reveal the grates, although the crucible would actually rest upon coke, as shown in *b*, a vertical section of the furnace with a covered crucible, surrounded with burning coke. At *c* are pick-up tongs used for removing the cover from the crucible, charging ingots, *d*, Tongs for lifting the white-hot crucible from the furnace. *e*, One-man shank for carrying and pouring small crucibles. *f*, Two-man shank for carrying large crucibles. *g*, Iron skimmer. Parts of the furnace are: *a*, Concrete floor, *b*, Brick or concrete foundation, *c*, Ash-pit, *d*, Grates *e*, Iron cylinder or oil drum, lined with fire-brick *f*, A charging hole, *g*, covered by a piece of fire-brick, *h*, is in the furnace cover, *i*, which is made of fire-bricks clamped together with iron bands, *j*; *k*, Heavy cast iron floor plate with a hole in the middle to match the inside diameter of the furnace. It is usually set level with the floor of the foundry (the furnace being built in a pit) so that the cover may be slid off on the floor when the coke is being charged or the crucible removed. At *l* is a flue connected to a chimney. If an electric fan or blacksmith's blower is connected to a closed ash-pit, this flue may be dispensed with, the products of combustion making their egress through the opening, *g*, the brick, *h*, being, of course, left off. The crucible, *m*, is shown with its molten metal covered with charcoal. *n*, The crucible cover (some melters do not use covers). *Courtesy Randolph Wardell Johnston, Technical Studies.*

Figure 55. An economical furnace for coke or gas firing, *manufactured by the Whiting Corporation of Harvey, Illinois.*

Figure 56. The Hausfeld gas fired furnace for vocational schools, pattern shops and testing laboratories, *manufactured by the Campbell-Hausfeld Co. of Harrison, Ohio.*

ing and maintaining the other crucibles or ladles required with the ordinary type furnace. Since there is no transfer of metals, the customary overheating is wholly eliminated.

The Iler Furnace is divided, as shown in the illustrations, on an inclined plane, the upper and lower parts being hinged. When closed, the upper part rests in an airtight seal, eliminating heat loss. A closed passage, built into the walls of the lower part, conducts the air from blower to burner. The air, passing through, picks up heat which would otherwise be lost and returns it to the combustion chamber. The air, thus heated, facilitates combustion, resulting in a short flame, retained down and around the crucible. Therefore, only a minimum is allowed to escape through the port in the cover.

Tests show that this preheating of air effects a saving of as much as 20 per cent in natural gas and a correspondingly greater saving where fuel oil is used. This also insures quick heating and higher temperatures where required for special purposes.

Designed for either gas or oil operation, the Iler Furnace is of sound, sturdy construction, easy and economical to operate.

The Fisher type "S.F." stationary floor furnace is designed for installation in lofts and similar locations where pits are impractical. Convenience of charging and pot removal has been greatly facilitated by the low construction of this furnace. Working height has been reduced by the elimination of supporting legs. A narrow ventilated sheet steel skirt is welded to the furnace bottom to provide an air space between the bottom of the furnace and the floor. The slag port is at the rear side of the furnace. Slag accumulation drains through this port to the foundry floor and in the event of pot failure, metal drains out in the same manner.

The Fisher "BBI" and "SM" tilting furnaces are heavy duty units, ruggedly constructed for continuous service.

The "BBI" furnace is designed for rapid melting, with low fuel cost. All spent combustion gases are routed through an opening between the top of the crucible and the furnace cover. These spent gases contact the top surface of the metal in the crucible, appreciably reducing melting time. The furnace shell is mounted on roller bearing trunnions and supported on substantial structural steel legs. The shell and furnace base are of welded construction and fabricated from blue annealed steel plate. Re-enforcing bars, welded to the furnace bottom, prevent warping or sagging. The tilting mechanism consists of a hand wheel, driven through a machined worm gear and pinion reducing gears. Fisher silicon carbide, pre-burned refractory shapes line the shell. All shapes are tongued and grooved on the connecting edges to insure a perfect union. Two types of insulating materials are used between the silicon carbide lining and the furnace shell to lessen escape of heat by conduction. The burner tip is totally enclosed within the furnace lining and attached to the furnace

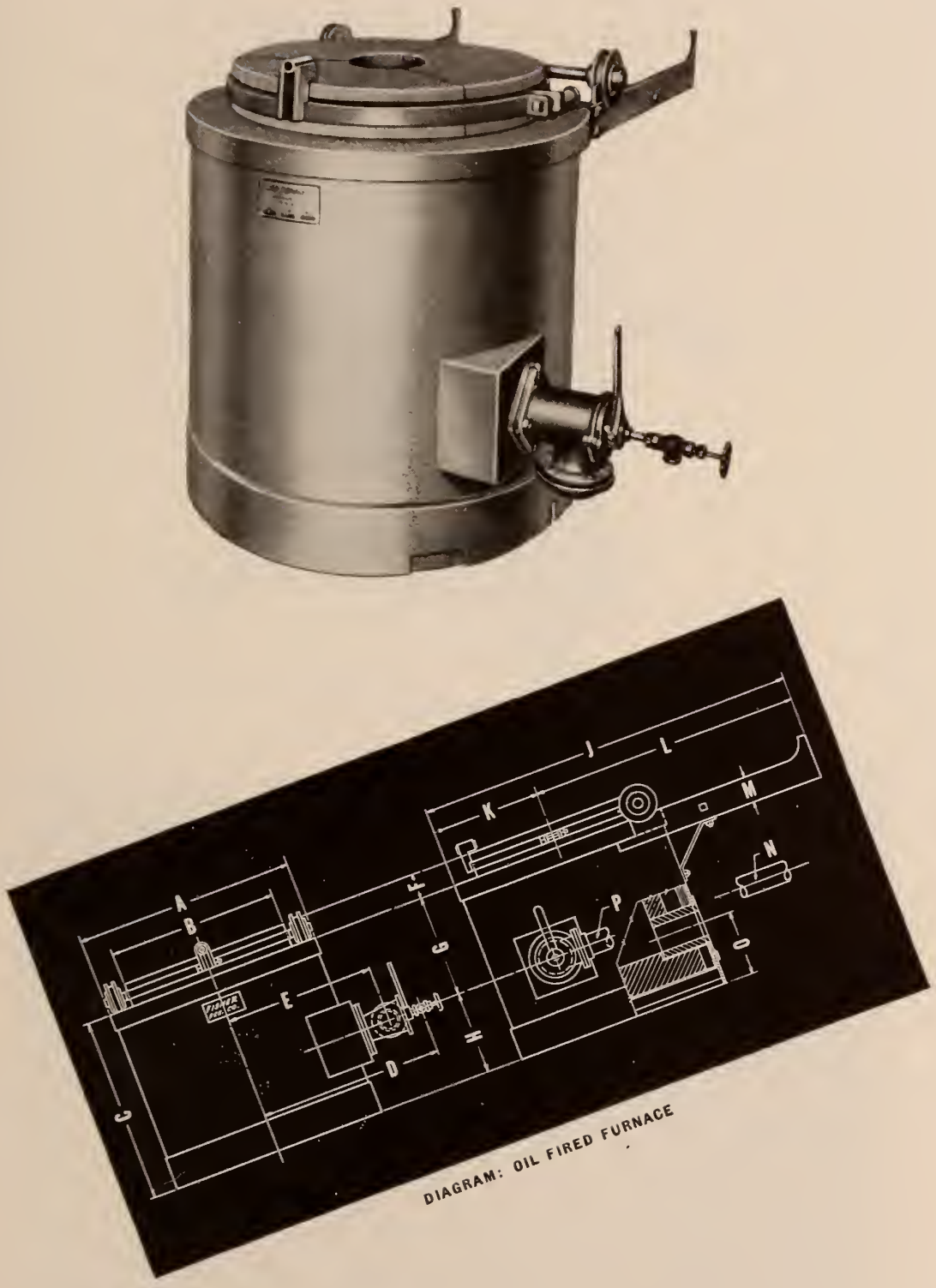

Figure 58. The Fisher "S.F." furnace, gas fired, oil fired. This is particularly adapted to lofts and similar locations where pits are impractical. Low construction facilitates charging and pot removal. Tangential mounting of burners assures even distribution of heat to the entire crucible surface. This furnace is recommended for copper, brass, bronze, copper-nickel alloys, aluminum and other non-ferrous alloys, gray iron and gray iron alloys. *Courtesy Fisher Furnace Division, Lindberg Engineering Co., Chicago, Illinois.*

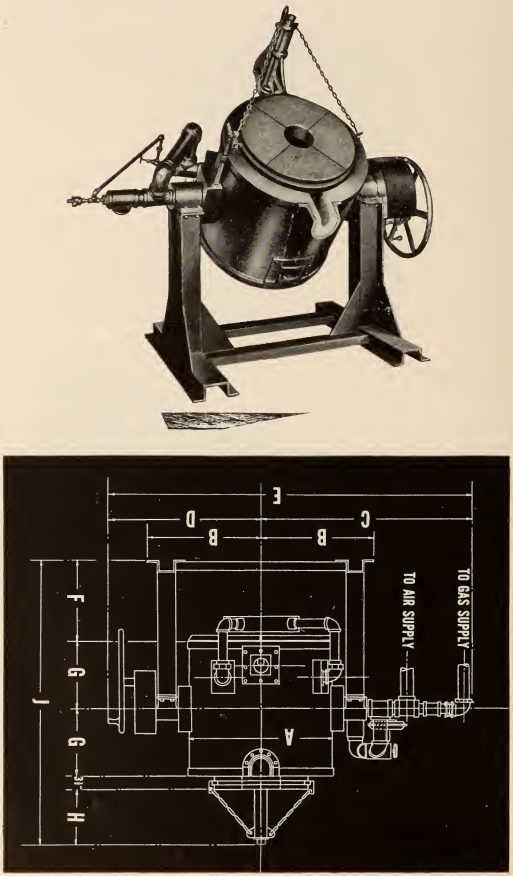

Figure 59. The Fisher "BBI" hand tilt furnace. a manual tilting type, gas or oil fired. This is a heavy duty unit, ruggedly constructed for continuous service and designed for rapid melting with low fuel cost. The burner assembly tilts with the furnace and fires at all angles throughout the pouring operation. This furnace is recommended for brass, bronze, yellow brass, copper-nickel alloys, iron and iron alloys. *Courtesy Fisher Furnace Division, Lindberg Engineering Co., Chicago, Illinois.*

drum. The burner assembly tilts with the furnace and can be fired at any angle throughout the pouring operation. One hundred per cent of the atomizing air is delivered to the burner mechanically, thus providing positive control of furnace atmospheres.

The "SM" furnace is especially designed for melting yellow brass and is structurally the same as the Fisher "BBI" furnace, with the exception that the space between the crucible top and the furnace cover is restricted to allow only 25 per cent of the spent gases of combustion to vent through the cover opening. The remaining 75 per cent of the spent gases is released through a flue located at the rear of the furnace shell. The restricted opening around the crucible, plus the increased area of the cover opening , as compared with the "BBI" furnace cover, reduces pressures over the crucible and also cuts down gas velocities over the metal. Zinc losses are materially reduced.

In starting the coke fired furnace, crumpled newspaper is placed at the bottom of the furnace to start the fire. A good supply of charcoal is added. After the charcoal has ignited and is burning, the coke is added. Charcoal is much better than wood for this purpose, since wood creates considerable smoke and fumes which escape in the foundry and harrass the workers.

The fire is usually made hot before the metal is put into the crucible to melt. Care must be taken that no pieces of metal are wedged in for these are likely to expand on heating and crack the crucible.

Only crucibles that are thoroughly dry should be used, as damp one crack and scale. Therefore, the crucibles when not in use should be kept close to fire at all times to prevent absorption of moisture from the atmosphere or dampness from other sources. Care must also be taken not to put a piece of wet metal into a crucible filled with molten metal. When the wet metal comes in contact with the melted metal, steam is created so rapidly that a minor explosion takes place and some of the liquid metal may be blown from the pot. Severe burns have been received as a result of such carelessness.

Regardless of the type of fuel used, i.e. gas, coke or oil, an air supply is essential for the best results and quick melting of the metal. With coke or gas the air is supplied from a cylinder blower and piped to the bottom of the furnace. If oil is used the air is supplied from a pressure tank and mixed with the oil in a gun type nozzle before entering the furnace. The pressure in the tank is kept at a uniform level by an automatic compressor.

For high temperatures the lid of the furnace, covering the crucible is kept in place. It should be removed only occasionally for quick inspections, as the heat is rapidly dissipated on its removal.

Precautions should be taken to prevent fires from exhaust gases and poisoning from carbon monoxide. Furnaces should not be placed

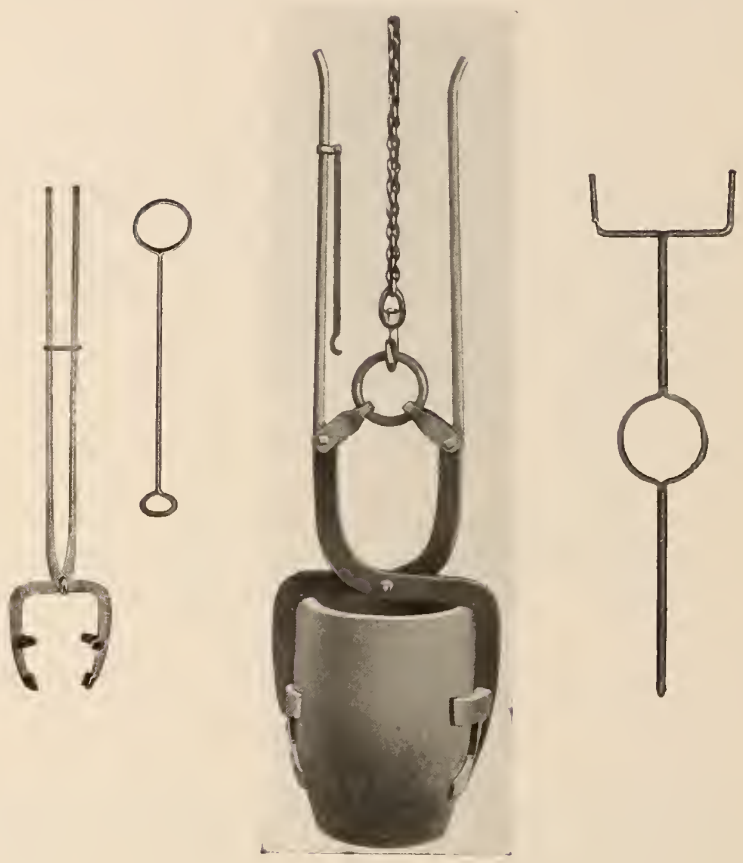

Figure 60. Standard crucible tongs and shanks. *Courtesy of the Whiting Corporation, Harvey, Illinois.*

in wooden buildings or near inflammable materials. Oil or gas should not be allowed to enter hot furnaces unless there is a flame present or unless the refractory material is red hot enough to ignite the fuel immediately; otherwise an explosion may take place when considerable gas or vaporized oil is ignited at one time. There must be sufficient ventilation at all times to prevent carbon monoxide poisoning.

The life of the equipment will be prolonged and better castings will result if the furnace temperatures are held only high enough to get the best results. These temperatures are beyond the range of ordinary thermometers, but may be determined with pyrometers. They may also be approximated with reasonable accuracy by observing the refractory walls of the furnace. The following table gives a good indication as to temperatures within the furnace.

Figure 61. *a*, The metal is put into the furnace, care being taken not to wedge cold metal particles in the crucible. *b*, After melting, the crucible is removed and placed in the shank shown at the bottom of the illustration.

CHAPTER XV

FINISHING THE CAST

After pouring and cooling, the mold is removed from the pit first pulling out the timbers. The crane may be used for this purpose. It is not necessary to be too careful, as the mold is now to be destroyed to obtain the cast. As a rule, the removal of the timbers does not cause the dirt to sink sufficiently to apply a rope around the mold for its removal from the pit. If the removal of the timbers does not cause the dirt to sink sufficiently, some of the dirt is shoveled from the pit until three-quarters of the mold shows above the earth. The mold then is tipped until enough space is allowed to slip the rope around the mold for lifting it out with the crane. In doing this the bottom of the mold may break off, but this makes little difference, since the mold has to be destroyed anyway. The mold is removed with the aid of the crane to the place where it is to be destroyed, usually near the ball or crushing mill for making luto. Luto, as prevoiusly explained, is nothing more than crushed or powdered silica-plaster molds. These crushing mills are also called tumbling barrels or ball mills. They are filled with luto and heavy weights of iron or stones. As the mill revolves the weights fall on the luto, thereby crushing and powdering it. Grinding mills for the same purpose may be purchased from foundry supply companies. Such a tumbling barrel is seen to the right in Figures 63 *b* and 64 *a*.

As the larger portions of the mold are removed with a small pickax or any other suitable instrument (Fig. 63 *a*), the pouring columns, gates and air vents begin to appear. However, they are now in metal instead of in wax (Fig. 63 *b*). The worker continues to remove the mold until he can see where the gates and air vents are attached to the cast. When he knows where and what to cut, he saws off the columns, gates and sprues or risers at strategic points (Fig. 64 *a*). This permits their easy removal. The hammering of the columns, gates and vents may create enough vibration to cause much of the remaining mold to fall away, but care must be taken not to hammer too much on a gate that is well sealed to the surface of the cast. If this is done on a thin cast, part of the surface of the cast may break away with the gate. When it is impossible to get into cramped areas to saw off a gate or vent, this may be removed with a sharp chisel (Fig. 64 *b*). The cut is made in the gate near the surface of the cast and at a wide angle to it, rather than at right angles to the cast. This prevents the gate from breaking off and forming a rough intaglio surface that later must be welded and then filed. It is well to bear in mind that a raised rough surface is easier to repair than a depressed surface. The raised surface may be filed away, whereas the depressed area must be welded and then filed.

Figure 63. *a*, The investment mold is broken away. *b*, The metal pouring funnel, columns, sprues, gates and base become visible.

Figure 64. *a,* The gates are sawed off near the cast. *b.* A sharp chisel may also be used to advantge in removing the rough areas that remain.

Figure 65. *a*, Core nails are cut in two with a sharp chisel. The piece that remains is pushed through the cast into the core. *b*, The cast is brushed comparatively clean with wire brushes.

The core nails are cut off near the surface with a chisel (Fig. 65 *a*). The cut end of the nail is then pushed through into the core and comes out when the core is removed.

When the cast is well trimmed of defects that may have been caused in the casting and the core nails are cut off and punched through, the cast is placed in the acid bath (Fig. 66 *b*). This consists of a vat containing one part of sulfuric acid to one hundred parts of water. A vat measuring four feet deep, three feet wide and four feet long is suitable for the average sized piece of sculpture, such as portraits, small garden figures and life-size figures which have been cast in two or more pieces. Such a vat should hold about three or four hundred gallons of the water-acid mixtures. If a piece of sculpture or section of a cast is so large that it will not be covered entirely by the solution, it may be put partially into the bath. After that section has soaked overnight, the cast is removed and the other portion soaked. The acid mixture is so weak that there will be no detrimental effects on the metal. These acid baths may be constructed below the ground level of concrete. They must be given one or two generous coatings of asphaltum paint before the acid is placed in them.

The object of the acid bath is to soften the core and clean the surface of any plaster-silica mixture, and further to prepare the surface of the cast for additional work. When the cast is removed from the acid bath, the copper tubes that were used to support the core during the baking are removed. A hooked rod is then used to macerate the core which has softened in the acid bath to a consistency of thick cream. This is washed out with a hose and water. The surface is cleaned with a wire brush as seen in Figure 67 *a*.

After cleaning with water, a flame is played on the cast to dry off the water (Fig. 67 *b*). When the cast is dry both inside and outside and the metal has cooled again, it is placed on the bench for the finishing or chasing. For example, all rough raised places left by the attachment of gates are chiseled off close to the surface. The surface is then filed smooth. Often this must be done in a manner to simulate the sculptor's original texture. A grinding machine fitted with various tools, such as wire brushes and grinders, helps in this procedure.

Threads are cut in the small holes left in the cast by the core nails or pins with a tap or thread cutting tool. A piece of metal rod is then threaded with a die to fit the tap threads that were made in the cast. The rod is then screwed into the cast and cut off with a hack-saw close to the cast. The metal rod should, of course, be of the same composition as the metal cast. For example, if the cast is bronze and composed of eighty-five parts copper, five parts lead, five parts tin, and five parts of zinc, then the rod should be of the same composition. Rods formed in air vents and parts of gates often may serve for this purpose, but it is a better policy to buy the rods already cast. They may be cast by using wood dowel pins as patterns, which are obtainable from lumber and hardware dealers. Sand molding foundries will cast them quite cheaply.

Figure 66. *a*, Another side of the cast after brushing. *b*, The cast is placed in a weak acid solution for cleaning and dissolving out the core.

Figure 67. *a*, The acid is washed away with water. *b*, It is then dried with a gas flame or blow torch.

CHAPTER XVI

DEFECTS AND THEIR REPAIR

Where there is a large hole or area to be repaired, as seen in Figure 68 *a*, it should be done with molten metal in the following manner. The edges of the hole are trimmed so that no feather edges will remain. Clay or plasteline is placed over the hole and worked smooth, as seen in Figure 68 *b*. To hold the clay in place and keep it from falling through, it may be necessary to back it up with paper or other material from inside the cast. After the clay has been modeled to match the surrounding structure and to replace the metal that was lost when the hole was made, pouring columns are added, as seen in Figure 69 *a*. These also are made of clay. Small pieces of clay are then added to give intaglio indicating points on the mold when it is applied. These can be seen as tiny beads in Figure 69 *a*. These beads indicate points for cutting out or drilling air vents. Clay cannot be used for this purpose because the clay would have to be so fine or strawlike that it would droop of its own weight or be removed during the application of the plaster-silica mixture in making the mold to cover the defect.

A wall of clay is then built around the modeled area to confine the plaster-silica mixture which will be placed over the clay to form the mold for the lost part (Figs. 69 *a* and *b*). Equal parts of plaster and silica are mixed and applied over this lost clay modeled area within the wall, as seen in Figure 69 *b*. After the mixture has set, the plaster and clay are removed (Fig. 70 *a*). The clay gates are picked out of the plaster and the air vents or risers are drilled or cut into the mold where they are indicated by the negative impression of the beads. These molds are placed on a fire and baked until they are thoroughly dry (Fig. 70 *b*). When dry they are allowed to cool. While the molds are cooling, wood is used to stop up the largest holes in the metal cast. Asbestos paper is forced into the cracks beside the wood and the cast by means of a punch, in order that the metal which will be poured later will not flow into the hollow within the cast. The paper is forced back for about a quarter of an inch under the edge of the metal surrounding the defect. Into this one-quarter of an inch are drilled one-eighth inch holes so that when the metal is poured it will flow up from the inside of the cast and lock the patch in place.

After the area to be patched is well packed with asbestos paper to prevent any leakage of metal into the hollow of the cast, the patch molds are replaced on the cast. They are tied securely to the cast with wire and the the seam where the patch molds join th cast is filled with clay so that no leakage of the metal will occur at this seam (Fig. 71 *a*).

In the meantime the metal is melted in a small crucible, for only enough to fill these patched areas is necessary. The metal is then poured

Figure 68. *a*, A defect shown in the hip and arm areas. *b*, The area on the hip is remodeled with clay or plastiline

Figure 69. *a*, A wall is built of clay around the remodeled area and clay pouring columns for the metal are installed.. *b*, The area is then covered with investment compound.

Figure 70. *a*, The molds are removed *b*, The molds are thoroughly dried over a gas flame.

Figure 71. *a*, After the defect has been packed with asbestos paper, the mold is replaced securely tied with wire. The metal is poured. *b*, The metal pouring columns on the leg still in place after the defect has been recast.

Figure 72. *a*, Small holes caused by core nails are drilled out smooth. *b*, They are then tapped with threads.

Figure 73. *a,* A piece of bronze rod is threaded and screwed into the tapped hole. *b,* It is then cut off close to the cast.

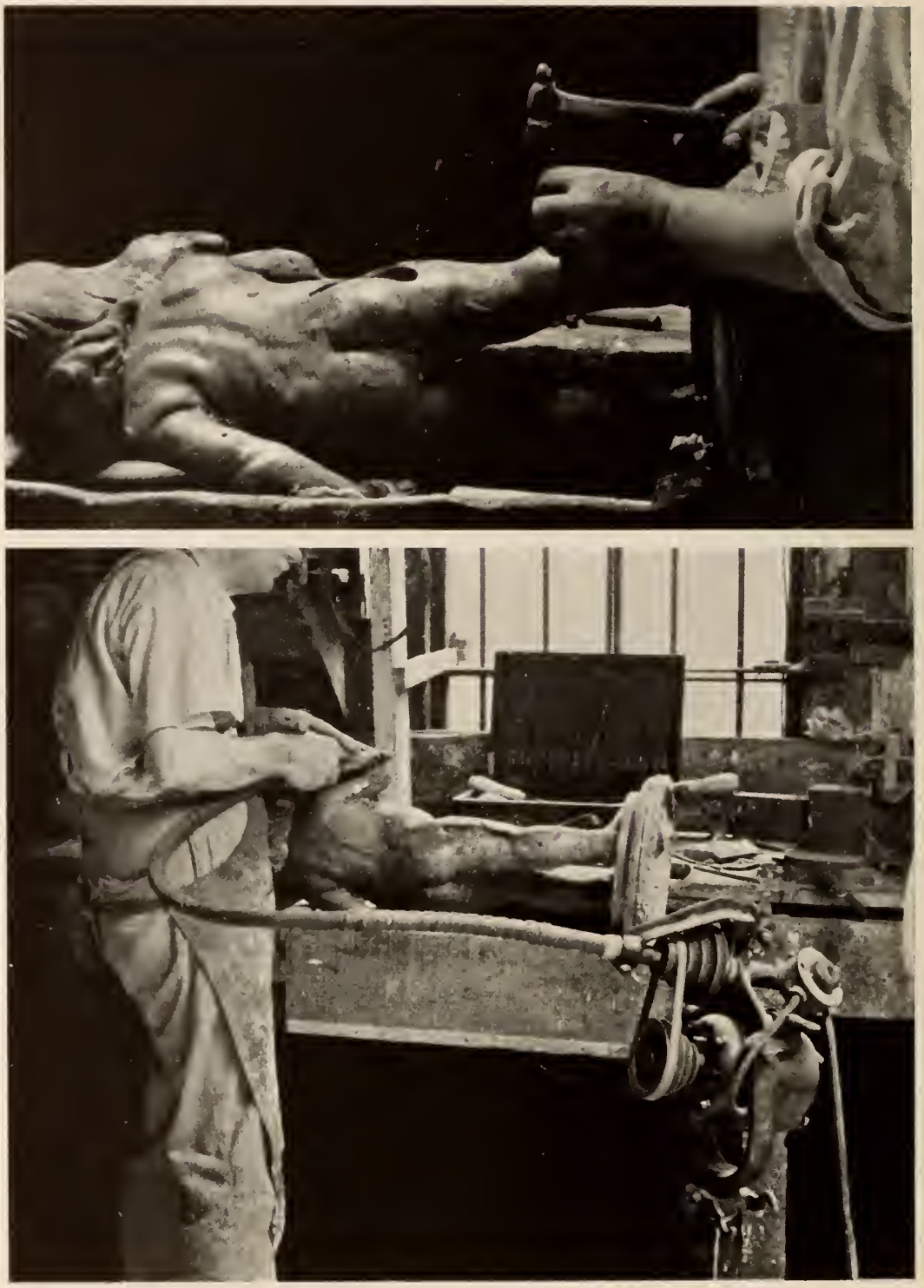

Figure 74. *a*, The area over the sawed off rod is tapped tight so it cannot become unscrewed. *b*, The area is then polished off.

Figure 75. *a*, Finishing of the cast can be accomplished with grinding wheels. The careful worker can duplicate the sculptor's technique of obtaining surface detail. b, Confined areas can be ground with special burrs.

into the patch mold. As soon as the metal sets and cools, the patch mold is broken away and the gates and air vents cut away. The work of finishing the cast proceeds as usual, as though no faulty casting had occured.

Large cracks or holes in the metal resulting from other conditions are repaired in the same way. Small defects in the metal may be repaired by simply melting a piece of metal riser or cast rod over the defect with an oxygen-acetylene blow torch. Later this area is chiseled, filed, ground and polished until it blends with the surrounding areas. If the hole or crack is large, the melted metal may flow through from the blow torch. To prevent this a piece of asbestos paper is placed under the hole and held in place with a ball of clay while the metal is melted and flowed into the crack.

Depressed areas are drilled out and tapped with threads (Figs. 72 and 73). A rod of correct size is threaded and screwed into the hole and partly cut near the surface of the cast with a chisel or a hack saw, then broken off. The remaining nub is hammered to spread its top end so that it will not come out of the cast. It is then filed down and chased to harmonize with or be lost in the surface texture. Various punches are used for this purpose. The sculptor often executes his surface textures in his own individual manner. Such textures can be duplicated on the patched metal surface, which may have been lost in the casting, with various grinding tools. punches, chisels and similar tools. Finally, the surface is cleaned by hand with emery cloth and wire brushes. Circular wire brushes of different grades of coarseness may also be used in a grinding device. The device may be an electric motor-driven drill holder that can be held in the hand. A machine that sits on the floor, with a cable extension to hold the drills, grinding tools, emery wheels and similar tools also may be employed.

CHAPTER XVII

PATINING OR METAL COLORING

When the metal cast has been polished to a point where all blemishes are removed it is ready for patining. There are numerous agents used for this purpose. For example, to create a green bronze effect, the bronze cast is heated with gas or a gasoline blow torch and a solution of copper nitrate is applied with a brush (Fig. 76 *b*). To create a black lead effect on a lead-antimony cast a muriatic acid solution is used A brown bronze effect on bronze may be obtained by the use of an iron nitrate solution. Sometimes dry pigments are mixed with the solution on the brush to create effects different from those obtained with the chemical solution alone. At intervals the bronze is washed off in cold water to prevent the chemical from being applied too thickly.

The technique involved in the coloring of metals is only obtained after some experience. The composition of the metal will effect the coloring to a great extent. Copper and its alloys will take color more readily than alloys low in copper and high in zinc such as pale brasses. However, much of the difficulty of chemical coloring can be overcome by electro-plating effects.

The thorough cleaning of the works is an important factor in obtaining a uniform color. An oil or oxide film will, in some instances, prevent metal from taking color. Therefore, the work should be thoroughly cleaned before coloring operations are begun. This is especially true when the metal is to be colored by a cold chemical process. After cleaning, pickling or bright dip operations, the work should be rinsed in water before immersion, temperature and the final brushing operations. Most large sculptures are colored or patinized by first heating the metal with a blow torch and then applying the solution with a brush. The metal should generally be sufficiently hot to cause the solution to sizzle on application. When small sculptures are produced in quantity more uniform results can be obtained by immersion or by electro-plating. With few exceptions, only the surface of the metal is affected. It is therefore necessary to protect the finished surface with a coating of wax, varnish, oil or lacquer, otherwise the coloring will be damaged either by handling or by exposure to the atmosphere. By use of these materials any degree of matte or gloss can be obtained. An application of wax without polishing produces a matte effect, or the high points alone may be polished. There are both matte and glossy liquid waxes, varnishes and lacquers. The waxes serve as better protection against moisture but are more subject to mechanical damage as they are easily brushed off. The varnishes and lacquers give better protection against mechanical damage but less protection against moisture. Some varnishes

Figure 76. *a*, The completed bronze figure before patining. *b*, Heat is applied and the chemicals are brushed on. *c*, In this case an antique light green bronze effect was produced. *d*, Notice that the surface is much lighter than in *a*.

Figure 77. The finished bronze figure in place in a garden.

and lacquers turn milky in the presence of moisture. This whitening effect is called *bloom*.

All formulas for coloring metal in this book are given in parts by weight. Therefore, small amounts can be compounded from them for the patinizing of a single small sculpture or large amounts can be compounded for mass production. In other words a few ounces of the solution as well as a few gallons can be made from the same formula.

Copper, copper deposits, or bronze, rich in copper, such as that containing: copper 90 per cent, tin 7 per cent, and zinc 3 per cent, or bronze containing: copper 85 per cent, tin 5 per cent, zinc 5 per cent, and lead 5 per cent may be finished in a variety of colors. This can be accomplished by immersion in the solution or by heating the metal and brushing on the solution. The following formulas are for bronze of this type:

YELLOWISH GREEN

	Parts by weight
Ammonium chloride	7
Copper acetate	4
Water	8

APPLE GREEN

Sodium chloride	5
Ammonia (household)	4
Ammonium chloride	5
Glacial acetic acid	4
Water	32

BLUISH GREEN

Sodium thiosulfate	1
Iron nitrate	8
Water	128

ANTIQUE GREEN

Copper sulphate	12
Ammonium chloride	2
Water	128

BROWN

Potassium sulfide	1
Barium sulfide	2
Ammonia (household)	4
Water	200 to 300

BROWN TO BLACK

Potassium sulfide	1
Water	128

This solution may be used either at normal temperature or heated to 150 degrees F. When used cold, light brown may be obtained and with longer immersions in the hot solution the darker shades are obtained. This solution will produce a wide variety of brown shades to black,

and is the most common in use. The concentration of the solution may be varied by the addition of an ammonium hydroxide.

BROWN

	Parts by weight	
Yellow barium sulfide	1	
Water	128	
Temperature	150F.	65.5C.

BROWN

Copper sulfate	5	
Glacial acetic acid	2	
Sodium hydroxide (lye)	2	
Water	64	
Temperature	160F.	71.1C.

BROWN

Antimony sulfide, golden, Sb_2S_5	1-2
Sodium hydroxide (lye)	4
Water	256

BLACK

Arsenious acid	2
Muriatic acid	4
Sulfuric acid	1
Water	64

Coloring or Patinizing Brass

The solutions used for coloring copper or bronze are also applicable for the most part to brass. Nevertheless the coloring of brass is more difficult. It may be necessary to repeat operations more frequently or prolong the immersion time or increase the concentration and temperature of the solution. These formulas are particularly applicable to the brushing technique on hot metal.

VERDE

	Parts by weight
Copper nitrate	1
Ammonium chloride	1
Calcium chloride	1
Water	32

This solution is operated at normal temperature. The object is immersed until a dull green color is obtained.

VERDE

	Parts by weight
Copper sulfate	8
Ammonium chloride	4
Sodium chloride	4
Zinc chloride	1
Glacial acetic acid	3
Water	128

This solution is operated at normal temperature. The work is immersed for a few minutes, then removed. After removel the solution is allowed to dry on the surface. It may be necessary to repeat the operation until the desired effect is obtained. The color effect may be produced more rapidly by heating to about 180 F for 1 to 2 hours.

GREEN

	Parts by weight
Sodium thiosulfate	4
Iron nitrate	1
Water	64

The work is immersed in the solution which is kept at 180 F until the green color develops. The object is dried and waxed or lacquered. High lights may be rubbed out if desired.

ANTIQUE GREEN

	Parts by weight
Ammonium chloride	14
Iron chloride	3
Sodium chloride	8
Verdigris powder	8
Potassium bitartrate	4
Water	128

The solution may be used at 93 C (200 F) or applied to the hot mersed. After immersion the surface can be stippled with a brush to give a variegated effect.

BROWN

	Parts by weight
Antimony sulfide (golden)	1
Sodium hydroxide (lye)	1
Water	32

The solution may be used at 93 C (200 F) or applied to the hot metal with a brush for the variegated effect.

BROWN

	Parts by weight
Copper sulfate	1
Potassium chlorate	1
Water	16

The object is immersed in the solution at normal temperature, then removed, dried, and waxed or lacquered.

BLUE

	Parts by weight
Sodium thiosulfate	4
Lead acetate	3
Water	64

The object is immersed in the solution at 82 C. (180 F.), removed, dried, and waxed or lacquered.

BLACK

	Parts by weight
Copper carbonate	2
Ammonium hydroxide	4
Sodium carbonate	1
Water	32

The object is agglutinated in the solution at 66-67 C. (150-170 F.), while it is immersed. The excess of copper carbonate is necessary. After drying, the object is waxed or lacquered.

Coloring Lead

BLACK

Lead and lead alloys may be made black by immersion or painting at normal temperature with the following solution:

	Parts by weight
Hydrochloric acid	4
Water	1

OTHER COLORS ON LEAD

From a sculptural standpoint lead casts have been only patinized black in the past. However, when one considers the various pigments that are made by oxiding lead with acetic acid and other oxidizing agents, it is logical to assume that lead casts could be patinized yellow, orange, red, brown, and gray to white, because lead oxides of these colors are in common manufacture, such as white lead (lead subcarbonate), letharge (lead monoxide), lead oxide, brown (lead peroxide), and red lead (lead oxide).

Experimentation can be conducted along these lines by emyloying the proper oxidizing agent directly onto the surface of the subject. To do this some study into the manfacturing of lead pigments would be necessary.

Coloring Silver

The finishing of silver electro deposits or cast silver is generally accomplished by using a sulfide solution producing a black film of silver sulfide. The following formulas may be considered.

BLACK AND GRAY

	Parts by weight
Potassium sulfide	1
Water	128

Use at a temperature of 77-82C., 170-180F.

	Parts by weight
Ammonium sulfide	1
Water	128

Use at a temperature of 77-82C., 170-180F.

The black sulfide of potassium is relatively hard while that of the ammonium is soft. After immersing or brushing the subject, it is scratch brushed either wet or dry to obtain a black luster. To obtain a grey relief finish a tampico or rag wheel may be employed with fine pumice and water. The object is then dried and waxed or lacquered.

Butler Silver

A fine Butler or scratch brush finish is obtained by first scratch brushing the base metal with a tampico wheel using pumice and water. The object is then silver plated and the brushing operation is repeated to remove smut from the deposit. The object is then scratch brushed wet with a fine crimped wire brass or nickel silver wheel. The object is then dried and lacquered.

French Grey

The operations for the grey finish are the same as for the Butler finish with the exception that the object is oxidized after the second scratch brushing. After oxidizing the high points are relieved by brushing with a steel crimped wire wheel using pumice and water. The object is then dried and lacquered.

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